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NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®)

Myelodysplastic Syndromes

Version 1.2025 — November 15, 2024

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NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

[NCCN Guidelines Index](#)
[Table of Contents](#)
[Discussion](#)

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Continue

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NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

[NCCN Guidelines Index](#)

[Table of Contents](#)

[Discussion](#)

[NCCN Myelodysplastic Syndromes Panel Members](#)

[Summary of the Guidelines Updates](#)

- [Initial Evaluation \(MDS-1\)](#)
- [Spectrum of Indolent Myeloid Hematopoietic Disorders \(MDS-2\)](#)
- [Additional Testing and Classification \(MDS-3\)](#)
- [Management of Lower-Risk Disease \(IPSS-R Very-Low-, Low-, Intermediate-Risk Disease \(MDS-4\)](#)
- [Management of Higher-Risk Disease \(IPSS-R Intermediate-, High-, Very-High-Risk Disease \(MDS-7\)](#)
- [Supportive Care \(MDS-8\)](#)

- [Pathologic-Morphologic Classifications of Myelodysplastic Neoplasms 2023 \(MDS-A\)](#)
- [Clinical Principles of Myelodysplastic/Myeloproliferative Neoplasm \(MDS/MPN\) Overlap Neoplasms \(MDS-A\)](#)
- [MDS/MPN Classification \(MDS-A\)](#)
- [AML-Defining Genetic Abnormalities: WHO 2022 and ICC \(MDS-A\)](#)
- [Prognostic Scoring Systems \(MDS-B\)](#)
- [Genes Frequently Somatically Mutated in MDS \(MDS-C\)](#)
- [Genetic Familial High-Risk Assessment: Hereditary Myeloid Malignancy Predisposition Syndromes \(MDS-D\)](#)
- [Gene Mutations Associated with Hereditary Myeloid Malignancy Predisposition Syndromes \(MDS-E\)](#)
- [Recommendations for Flow Cytometry \(MDS-F\)](#)

[Abbreviations \(ABBR-1\)](#)

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See [NCCN Categories of Evidence and Consensus](#).

NCCN Categories of Preference: All recommendations are considered appropriate.

See [NCCN Categories of Preference](#).

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Updates in Version 1.2025 of the NCCN Guidelines for Myelodysplastic Syndromes from Version 3.2024 include:

General

- References updated throughout the Guidelines.
- "Or relapse" added to "no response" throughout algorithm.
- Footnote ee added to "or relapse" throughout algorithm: Reevaluation with bone marrow and/or molecular testing is recommended.

MDS-1

- Initial evaluation, bullet 4, previous bullet moved as last sentence: Genetic testing for somatic mutations (ie acquired mutations) in genes associated with myelodysplastic syndromes (MDS).

MDS-1A

- Footnote b modified: See *Table of Common Cytogenetic Abnormalities (MDS-A [4 of 5])*. (Also for footnote d).
- Footnote c added: If MDS is read out by the evaluating pathologist, reflex testing including cytogenetics and molecular testing should be performed as a standard practice. A unified report that includes molecular-genetic results with pathological description is required for appropriate diagnosis and therapy selection. See *Table of Common Cytogenetic Abnormalities in MDS (MDS-A [4 of 5])*.

MDS-2

- Footnote p, last sentences added: The CHRS may have a role in clinical decision-making but requires confirmatory evidence to help assess its efficacy. Another method has also been reported to aid in the prediction of clonal hematopoiesis to myeloid neoplasm.

MDS-3

- Footnote t, sentence removed: All full siblings should be evaluated for HLA match prior to unrelated donor match.
- Footnote u modified: Patients with CMML with PDGFRB rearrangement may have disease that responds well to tyrosine kinase inhibitors such as imatinib mesylate. Some patients may have somatic copy neutral loss of heterozygosity (cnLOH), especially those encompassing JAK2 mutations. CMML with eosinophilia as well as other myeloid and lymphoid malignancies with rearrangement of PDGFRB (locus 5q32) have constitutive activation of the tyrosine kinase receptor. Spleno- or hepato-megaly are common clinical features. Such diseases are considered unique entities by WHO and are exquisitely sensitive to imatinib (Shomali W, et al. Am J Hematol 2022;97:129-148). (See *MDS/MPN Classification Table on MDS A [3 of 5]*).

MDS-4

- Treatment, symptomatic anemia, node modified: del(5q) ± one other cytogenetic abnormality (except those involving chromosome 7) IPSS Low/ Intermediate-1 (Also for MDS-5).
- Clinically relevant thrombocytopenia or neutropenia, second-line treatment, regimens added:
 - ▶ Ivosidenib (if mutant IDH1 [mIDH1])(category 2B)
 - ▶ Olutasidenib (if mIDH1)(category 2B)
- Clinically relevant thrombocytopenia or neutropenia, rightmost column, If mIDH1, regimen added: Olutasidenib (category 2B) if IDH1 inhibitor not previously used.

MDS-5

- Treatment options revised to include preference stratification. (Also for MDS-6)
- MDS-SF3B1 (low blasts); No response or relapse and Serum EPO >500mU/mL; Preferred:
 - ▶ Regimen modified: Imetelstat (*if not previously used*)
 - ▶ Regimen added: Luspatercept-aamt (category 1)(*if not previously used*).
- MDS-SF3B1 (low blasts), last column, regimen added: Olutasidenib (if mIDH1)(category 2B).
- Last column for both MDS-5q (low blasts) and MDS-SF3B1 (low blasts), "(poor probability to respond to IST)" removed.

MDS-6

- Serum EPO ≤ 500 mU/mL, last column, Useful in Certain Circumstances, regimen added: Olutasidenib (if mIDH1)(category 2B).
- Serum EPO >500 mU/mL, Poor probability to respond to IST, last column if mIDH1, regimen added: Olutasidenib (category 2B) if IDH1 inhibitor not previously used.

[Continued](#)

UPDATES



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Updates in Version 1.2025 of the NCCN Guidelines for Myelodysplastic Syndromes from Version 3.2024 include:

MDS-6A

- Footnote ii added: An FDA-approved biosimilar is an appropriate substitute for any recommended systemic biologic therapy in the NCCN Guidelines. (Also for MDS-8A)
- Footnote mm added: Consider epoetin alfa or darbepoetin alfa if serum EPO ≤200 mU/mL.
- Footnote ss modified: Patients *with a good probability to respond to IST* are generally ≤60 years and with ≤5% marrow blasts, or those with hypocellular marrows, PNH clone positivity, or STAT3-mutant cytotoxic T-cell clones, whereas patients *with a poor probability to respond to IST* lack these features.
- Footnote removed: Refers predominantly to patients with lower-risk IPSS-R and IPSS MDS.
- Footnote removed: Per WHO 2022, this entity is now noted as MDS-SF3B1 (low blasts) (Khoury JD, et al. Leukemia 2022;36:1703-1719). See MDS-A 1 of 5.
- Footnote removed: Patients lack features listed in footnote qq.
- Footnote removed: An FDA-approved biosimilar is an appropriate substitute for epoetin alfa. (also for MDS-8A).

MDS-7

- Treatment for Higher-Risk Disease extensively revised.
 - Transplant candidates, regimens added:
 - ◊ Azacitidine + ivosidenib (if mIDH1)(category 2B) followed by allo-HCT
 - ◊ Azacitidine + olutasidenib (if mIDH1)(category 2B) followed by allo-HCT
 - ◊ Azacitidine ± venetoclax (Also for Non-transplant Candidates)
 - ◊ Decitabine ± venetoclax (Also for Non-transplant Candidates)
 - ◊ Oral decitabine and cedazuridine ± venetoclax (Also for Non-transplant Candidates)
 - Transplant candidates, if no response and if mIDH1, regimens added:
 - ◊ Single-agent olutasidenib (category 2B) followed by allo-HCT.
 - ◊ Azacitidine + olutasidenib (category 2B) followed by allo-HCT.
 - Non-transplant candidates, regimens added:
 - ◊ Ivosidenib (category 2B) ± azacitidine (if mIDH1)(category 2B)
 - ◊ Olutasidenib + azacitidine (if mIDH1)(category 2B).
 - Non-transplant candidates, if no reponse or intolerance or relapse and if mIDH1, regimen added: Olutasidenib (category 2B) if IDH1 inhibitor not previously used.

MDS-7A

- Footnote aaa added: The addition of venetoclax is based on patient status and tolerance.
- Footnote zz and footnote ccc were separated from one footnote.
- Footnote ccc, modified as follows:
 - ▶ Sentence removed: Clinical trials are preferred (Discussion).
 - ▶ Language added: Furthermore, a diagnosis of AML may be made with less than 20% in patients with certain cytogenetic abnormalities per ICC...
 - ▶ Language added: Per recent communications, some patients with higher risk disease with WHO 2022 MDS-IB2 and ICC MDS/AML could be considered for AML-type therapy...
- Footnote eee added: For HMAs, if no response within 6 cycles of azacitidine or 4 cycles of decitabine or oral decitabine and cedazuridine.
- Footnote removed: It is recommended to repeat molecular testing to identify targetable mutations.

MDS-8

- Bullet 6, post-transplant, sub-bullet 1 modified: Patients should receive *antibiotic antimicrobial* prophylaxis at least as long as they are on IST.
- Footnote jjj added: Ophthalmic and auditory tests are recommended annually when using deferasirox. Monitor serum creatinine regularly upon starting deferasirox.

[Continued](#)

UPDATES



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Updates in Version 1.2025 of the NCCN Guidelines for Myelodysplastic Syndromes from Version 3.2024 include:

MDS-A (1 of 5)

- Footnote c modified: $\geq 20\%$ marrow blasts or $\geq 10\%$ blasts those with AML-defining molecular abnormalities.

MDS-A (3 of 5)

- Footnote l modified: 10% to <20% bone marrow blasts or blast equivalents.
- Footnote t modified: Patients with CMML may have disease that responds to ruxolitinib for symptomatic disease....Consider exclusion of other abnormalities associated with myeloid/lymphoid neoplasms with eosinophilia and tyrosine kinase gene fusions (ie, PDGFRA/PDGFRB-r, FGFR1-r, or PCM1::JAK2, using FISH or RNA sequencing) to establish diagnosis of CMML....Molecular testing with a high-sensitivity PCR is required to detect KIT D816V.

MDS-A (4 of 5)

- Page header added: Genetic/Cytogenetic Abnormalities in AML and MDS.
- AML-Defining Genetic Abnormalities: WHO 2022 and ICC, table revised:

► AML

- ◊ Bullet 9 modified: CEBPA (WHO only), in-frame bZIP CEBPA mutations (ICC only).
- ◊ Bullet 10 modified: RBM15::MRTFA fusion (WHO only).
- ◊ Bullet 11 modified: NUP98 rearrangement (WHO only).

- Table added: Common Cytogenetic Abnormalities in MDS.

- Footnote aa added: Both the IPSS and IPSS-R rely heavily on cytogenetics; if a proper metaphase karyotype is non-informative/cannot be performed, the minimum recommended panel for FISH consists of abnormalities noted with an asterisk. Of note, there is also FISH for TP53.
- Footnote bb added: Both WHO and ICC recommend that without morphologic dysplasia, clonal cytogenetic abnormalities like loss of chromosome 13 or del(13q), del(9q), etc, which were considered as presumptive MDS should not be used to diagnose MDS but handled in the same way as CHIP mutations.

MDS-C (2 of 4)

- UBA1, examples of typical somatic mutation types and locations... row modified: Missense: exon 3 M41T, M41V, M41L, and others
- Footnote f added: Consider consulting a rheumatologist. JAK2 inhibitors and/or HMAs may potentially be used for these patients.

MDS-D (1 of 6)

- Whom to test, bullet 3 modified: All patients <50 y with MDS or AML and adults <50 y with AML

MDS-D (5 of 6)

- Management considerations added: The presence of a syndrome with noted high penetrance of myeloid malignancy or high-risk findings (such as somatic 2nd hit of RUNX1, DDX41, CEBPA, or biallelic TP53 loss) warrants timely referral to an academic center for assessment by a team with expertise in HMMPS and HCT evaluation for appropriate timing.

MDS-E

- Gene Mutations Associated with Hereditary Myeloid Malignancy Predisposition Syndromes
- Section extensively revised.



INITIAL EVALUATION

Cyopenia(s),
suspect
myelodysplasia^a

- History and physical (H&P)
- Complete blood count (CBC), platelets, differential, reticulocyte count
- Examination of peripheral blood smear
- Bone marrow aspiration with iron stain + biopsy + cytogenetics by standard karyotyping.^b Recommend testing bone marrow sample with reticulin stain for fibrosis. Genetic testing for somatic mutations (ie, acquired mutations) in genes associated with myelodysplastic syndromes (MDS)^{c,d}
- Serum erythropoietin (EPO) (prior to red blood cell [RBC] transfusion)
- Serum or RBC folate and vitamin B12 evaluation^e
- Serum ferritin, iron, total iron-binding capacity (TIBC)
- Documentation of transfusion history
- Thyroid-stimulating hormone (TSH)
- Lactate dehydrogenase (LDH)
- Recommend additional molecular and genetic testing for heritable hematologic malignancy predisposition in a subset of patients, particularly in patients^f <50 y
- Human immunodeficiency virus (HIV) testing if clinically indicated
- Consider evaluation of copper deficiency in patients with gastrointestinal (GI) malabsorption, severe malnutrition, gastric bypass surgery, or patients on zinc supplementation
- Consider distinction from congenital sideroblastic anemia (CSA)^g

Diagnostic criteria
for MDS not met
but cyopenias
present

[Spectrum of
Indolent Myeloid
Hematopoietic
Disorders \(MDS-2\)](#)

Diagnosis of MDS
established based
on morphologic,
cytogenetic, and
clinical criteria^{h,i}

[Additional Testing
and Classification
\(MDS-3\)](#)

Note: All recommendations are category 2A unless otherwise indicated.

[Footnotes on MDS-1A](#)



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

FOOTNOTES FOR INITIAL EVALUATION OF MDS

- ^aMDS is also suspected in the presence of peripheral blood dysplasia, blasts, or MDS-associated cytogenetic abnormalities. Cytopenias are defined as values lower than standard lab hematologic levels, being cognizant of age, sex, ethnic, and altitude norms. Greenberg PL, et al. Blood 2016;128:2096-2097. For diagnostic features of primary and therapy-related MDS that require cytopenia(s) and hematopoietic cell dysplasia, see [MDS-A \(1 of 5\)](#).
- ^bIf standard cytogenetics (with ≥ 20 metaphases) cannot be obtained, a chromosome microarray analysis (CMA; also known as chromosome array testing [CGAT]) or MDS-related fluorescence in situ hybridization (FISH) panel should be performed. If karyotype is normal, then consider CMA. Note that CMA will detect not only somatic but also constitutional (germline) changes. See Table of Common Cytogenetic Abnormalities in MDS ([MDS-A \[4 of 5\]](#)).
- ^cIf MDS is read out by the evaluating pathologist, reflex testing including cytogenetics and molecular testing should be performed as a standard practice. A unified report that includes molecular-genetic results with pathological description is required for appropriate diagnosis and therapy selection. See Table of Common Cytogenetic Abnormalities in MDS ([MDS-A \[4 of 5\]](#)).
- ^dBone marrow or peripheral blood cells should be assayed for MDS-associated gene mutations using gene panels that include genes listed on [MDS-C](#). These gene mutations can establish the presence of clonal hematopoiesis, which can help exclude benign causes of cytopenias in cases with non-diagnostic morphology, but do not establish a diagnosis of MDS in the absence of clinical diagnostic criteria (see [Genes Frequently Somatically Mutated in MDS \[MDS-C\]](#) and [Discussion](#)). As clonal hematopoiesis is a frequent consequence of aging, the finding of mutations in MDS-associated genes should be interpreted with caution and does not in isolation establish a diagnosis of MDS. The majority of patients with WHO-defined MDS have a somatic mutation detected in one of the commonly mutated MDS-associated genes. See Table of Common Cytogenetic Abnormalities in MDS ([MDS-A \[4 of 5\]](#)).
- ^eRBC folate is a more representative measure of folate stores and is the preferred test to serum folate. Serum methylmalonic acid testing is an accurate way to assess B12 status and is mandatory to the vitamin B12 evaluation, particularly for patients with possible pernicious anemia.
- ^fA heritable hematologic malignancy predisposition syndrome may account for cytopenias with or without MDS in some patients, whether presenting to pediatric or adult care centers (eg, GATA2 deficiency syndrome, Shwachman-Diamond syndrome, telomere biology disorders). Functional laboratory studies and constitutional (germline) genetic testing using large next-generation sequencing (NGS) panels to include genes listed on [MDS-E](#), whole exome or whole genome sequencing complemented with in silico copy number variant (CNV) calling, and/or laboratory analysis for CNVs, such as microarray testing are recommended for patients as shown on [MDS-D \(1 of 6\)](#). See [Genetic Familial High-Risk Assessment: Hereditary Myeloid Malignancy Predisposition Syndromes \(MDS-D\)](#) and [Gene Mutations Associated with Hereditary Myeloid Malignancy Predisposition Syndromes \(MDS-E\)](#).
- ^gIn patients <40 y, CSA is due to disordered mitochondrial heme synthesis, often with distinctive mutational and clinical features. Some of these patients will have disease that responds to pyridoxine or thiamine. CSA is not MDS (Fleming MD. Hematology Am Soc Hematol Educ Program 2011;2011:525-531). CSA may appear late due to lyonization in X-linked sideroblastic anemia.
- ^hConfirm diagnosis of MDS according to WHO/International Consensus Classification (ICC) criteria for classification ([MDS-A](#)) with application of International Prognostic Scoring System (IPSS) or revised IPSS (IPSS-R) ([MDS-B 1 of 4](#)). The percentage of marrow myeloblasts based on morphologic assessment (aspirate smears preferred) should be reported. Flow cytometric estimation of blast percentage should not be used as a substitute for morphology in this context. In expert hands, expanded flow cytometry (FCM) may be a useful adjunct for diagnosis in difficult cases (see *Initial Evaluation* in the [Discussion](#)).
- ⁱPatients with karyotypes t(8;21), t(15;17), or inv(16) are considered to have AML even if the marrow blast count is less than 20%. See [AML-Defining Genetic Abnormalities: WHO 2022 and ICC \(MDS-A 4 of 5\)](#) and [NCCN Guidelines for Acute Myeloid Leukemia](#).

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

SPECTRUM OF INDOLENT MYELOID HEMATOPOIETIC DISORDERS^{j-p,1-4}

Feature	CHIP	ICUS	Lower-Risk CCUS	High-Risk CCUS
Cytopenia(s)	-	+	+	+
Dysplasia	-	-	-	-
Clonality	+	-	+	+
Risk of transformation	+	+/-	++	+++
Clinical approach	Observation; Monitor based on clinical change	Observation; Monitor yearly	Observation; Monitor yearly	Observation; Monitor 2–4x/year CBC; consider clinical trial

CHIP: clonal hematopoiesis of indeterminate potential; ICUS: idiopathic cytopenia of unknown significance; CCUS: clonal cytopenia of undetermined significance

^j Regular monitoring of blood counts in these patients should be instituted after evaluation as in [MDS-1](#) (generally at least every 3–6 months). Monitoring is ultimately at clinical discretion, but these frequencies are reasonable based on risk of transformation. Molecular evidence (testing suggested on [MDS-1](#)) of clonal hematopoiesis provides information to allow earlier identification of predisposition states for myeloid neoplasms.

^k For patients with MDS, see [MDS-4](#), [MDS-5](#), [MDS-C](#), and [MDS-D](#).

^l Has one or more of these (+) features: either has a clonal karyotypic abnormality (present in ≥2 metaphases) and/or a somatic mutation (present at >2% variant allele frequency [VAF]). Evaluation of mutations should include sequencing or panels incorporating the most frequently mutated MDS-related genes as noted on [MDS-C](#). Somatic mutations in more rarely mutated genes can also provide evidence for CHIP or CCUS.

^m Patients with pathogenic mutations with >10% VAF AND ≥2 somatic mutations, spliceosome gene mutations, or mutations of *RUNX1* or *JAK2* have positive predictive values for myeloid neoplasms (MDS, MPN, or AML). Isolated mutations of *DNMT3A*, *TET2*, and *ASXL1* have less predictive value.

ⁿ *DNMT3A*, *TET2*, *ASXL1*, *RUNX1*, *JAK2*, *PPM1D*, *TP53*, and splicing factor genes are the most frequently mutated genes associated with CHIP.

^o Myeloid neoplasm risk is increased 3-, 37-, and 348-fold in low-risk, intermediate-risk, and high-risk CHIP/CCUS, respectively, compared to unmutated controls.¹

^p To facilitate clonal hematopoiesis risk score (CHRS) adoption, an online calculator is available and should be considered by the clinician evaluating the patient¹: <http://www.chrsapp.com>. The calculator returns a score with its corresponding risk category as low (CHRS ≤9.5), intermediate (CHRS 10–12), and high (CHRS ≥12.5). The three risk strata significantly differ in the 10-year probabilities of myeloid neoplasms and overall survival for relevant clinical discussions and follow-up. The CHRS may have a role in clinical decision-making but requires confirmatory evidence to help assess its efficacy. Another method has also been reported to aid in the prediction of clonal hematopoiesis to myeloid neoplasm.⁵

¹ Weeks LD, et al. NEJM Evid 2023;2:EVIDoa2200310.

² Malcovati L, et al. Blood 2017;129:3371-3378.

³ Galli A, et al. Blood 2021;138:965-976.

⁴ Kwok B, et al. Blood 2015;126:2355-2361.

⁵ Gu M, et al. Nat Gen 2023;55:1523-1530.

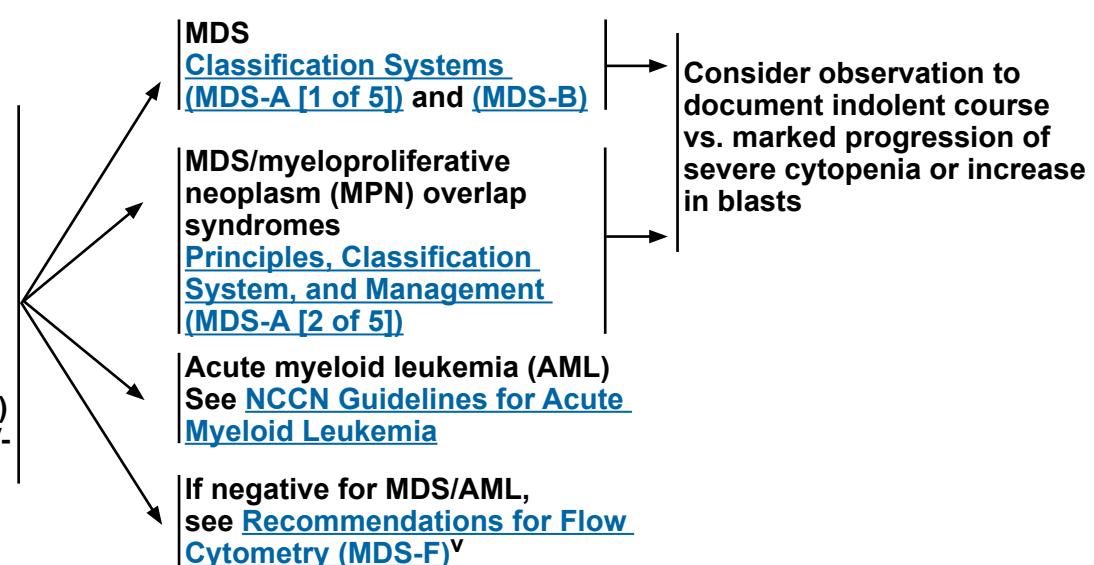
Note: All recommendations are category 2A unless otherwise indicated.



ADDITIONAL TESTING

- Consider flow cytometry (FCM) for MDS as a diagnostic aid^q and consider FCM and TCR polymerase chain reaction (PCR) and STAT3 mutation testing to evaluate for large granular lymphocyte (LGL)^r and paroxysmal nocturnal hemoglobinuria (PNH) clone^s
- Perform human leukocyte antigen (HLA) typing if hematopoietic cell transplant (HCT) candidate^t
- Consider evaluating patients with chronic myelomonocytic leukemia (CMML) for *PDGFRβ* gene rearrangements at 5q32^u
- Cytomegalovirus (CMV)-safe (CMV-negative or leukopheresed) blood products are recommended whenever possible for CMV-negative transplant candidates

CLASSIFICATION



^q See [Recommendations for Flow Cytometry \(MDS-F\)](#) and [Discussion](#).

^r Marrow or peripheral blood cell FCM may be assayed, and T-cell gene rearrangement studies may be conducted if LGLs are detected in the peripheral blood. STAT3 mutations are commonly found in T-cell LGL (T-LGL) disease. Morgan EA, et al. Blood Adv 2017;1:1786-1789. Chan WC, Foucar K, Morice WG, Matutes E. T-cell large granular lymphocytic leukemia. In: Swerdlow SH, Campo E, Harris NL, et al. WHO classification of tumours of haematopoietic and lymphoid tissues (ed 4th). Lyon: IARC Press; 2017:348-350.

^s FCM analysis of granulocytes and monocytes from blood with FLAER (fluorescent aerolysin) and at least one glycoprophatidylinositol-anchored protein to assess the presence of a PNH clone. DeZern AE, et al. Cytometry B Clin Cytom 2018;94:16-22.

^t Donors should be evaluated by high-resolution allele-level typing for HLA-A, -B, -C, -DR, and -DQ.

^u CMML with eosinophilia as well as other myeloid and lymphoid malignancies with rearrangement of *PDGFRB* (locus 5q32) have constitutive activation of the tyrosine kinase receptor. Spleno- or hepato-megaly are common clinical features. Such diseases are considered unique entities by WHO and are exquisitely sensitive to imatinib (Shomali W, et al. Am J Hematol 2022;97:129-148). (See MDS/MPN Classification Table on [MDS-A \[3 of 5\]](#)).

^v Mutation panel may be useful in this context to validate indolent myeloid hematopoietic disorders.

Note: All recommendations are category 2A unless otherwise indicated.

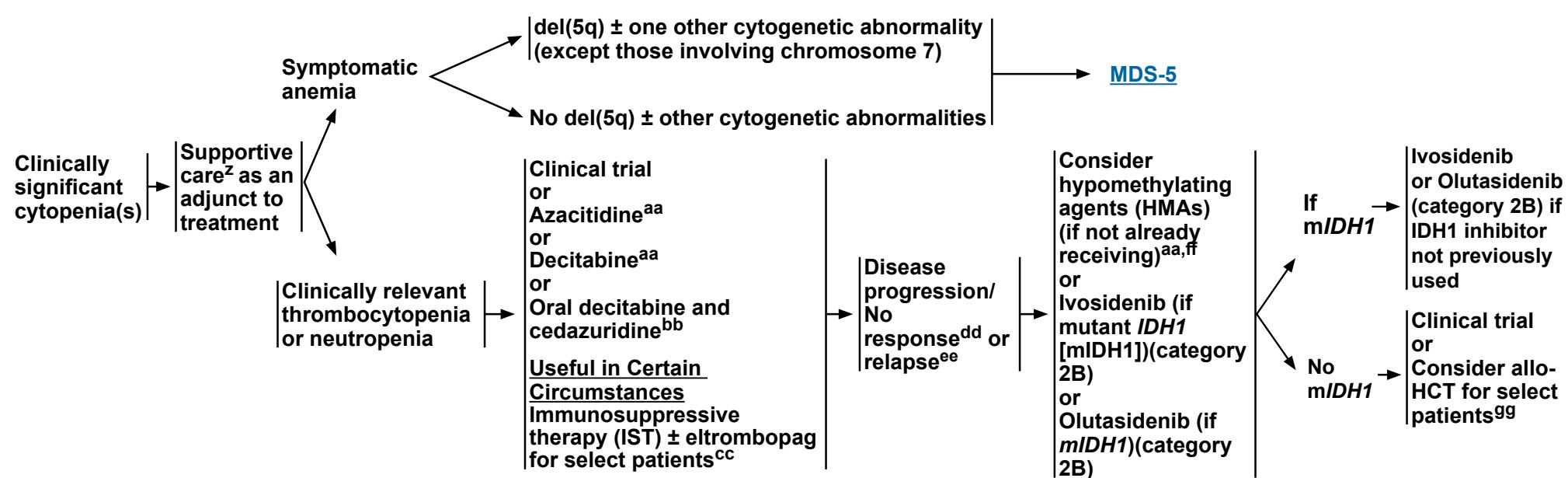


NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MANAGEMENT OF LOWER-RISK DISEASE (IPSS-R VERY-LOW-, LOW-, INTERMEDIATE-RISK DISEASE)^{w,x,y}

TREATMENT



^w Presence of comorbidities should also be considered for evaluation of prognosis (see *Comorbidity Indices* in the [Discussion](#)).

^x Given its more accurate risk stratification, the IPSS-R categorization is preferred although the other systems also have good value. IPSS-R Intermediate-Risk MDS may be managed as lower risk if their score is ≤ 3.5 vs. higher risk if their score is > 3.5 . Pfeilstöcker M, et al. Blood 2016;128:902-910.

^y If the disease is initially managed as lower risk but fails to respond, move to higher risk management strategies.

^z See [Supportive Care \(MDS-8\)](#).

^{aa} Some studies have demonstrated clinical benefit with low doses of azacitidine or decitabine for lower-risk MDS. Sasaki K, et al. NEJM Evid 2022;EVIDoaa2200034.

^{bb} Oral decitabine and cedazuridine (DEC-C) could be a substitution for intravenous decitabine in patients with IPSS Intermediate-1 and above. Garcia-Manero G, et al. Lancet Haematol 2024;11:e15-e26.

^{cc} Patients generally ≤ 60 y and with $\leq 5\%$ marrow blasts, or those with hypocellular marrows, PNH clone positivity, or STAT3-mutant cytotoxic T-cell clones. IST includes equine antithymocyte globulin (ATG) \pm cyclosporin A. Additionally, for severe thrombocytopenia, eltrombopag alone could be considered.

^{dd} Treatment failure would be considered if no response within 3–6 months. Response should be evaluated based on International Working Group (IWG) criteria: Cheson BD, et al. Blood 2006;108:419-425; Platzbecker U, et al. Blood 2019;133:1020-1030.

^{ee} Reevaluation with bone marrow and/or molecular testing is recommended.

^{ff} For patients with severe or refractory thrombocytopenia, eltrombopag or romiplostim can be considered. Oliva EN, et al. Lancet Hematol 2017;4:e127-e136. Fenaux P, et al. Br J Haematol 2017;178:906-913. See [Discussion](#).

^{gg} Patients with IPSS Intermediate-1, IPSS-R Intermediate, and WHO-Based Prognostic Scoring System (WPSS) Intermediate-Risk MDS with severe cytopenias would also be considered candidates for HCT. Matched sibling, unrelated donor, haploidentical donor, or cord blood donor, including standard and reduced-intensity preparative approaches, may be considered.

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MANAGEMENT OF LOWER-RISK DISEASE (IPSS-R VERY-LOW-, LOW-, INTERMEDIATE-RISK DISEASE)^{w,x,y}

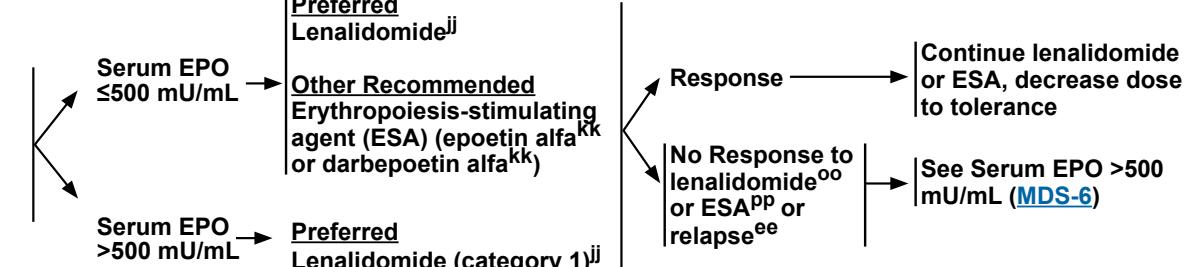
EVALUATION OF RELATED ANEMIA

- H&P
- CBC, platelets, differential, reticulocyte count
- Examination of peripheral blood smear
- Bone marrow aspiration with iron stain + biopsy + cytogenetics
- Serum EPO level
- Rule out coexisting causes

- Treat coexisting causes
- Replace iron, folate, B12 if needed
- RBC transfusions (CMV-safe)
- Supportive care^z

MDS-5q
(low blasts)
del(5q) ± one other
cytogenetic abnormality
(except those involving
chromosome 7)

TREATMENT OF SYMPTOMATIC ANEMIA^{hh,ii}



FOLLOW-UP

Response → Continue lenalidomide or ESA, decrease dose to tolerance
 No Response to lenalidomide^{oo} or ESA^{pp} or relapse^{ee} → See Serum EPO > 500 mU/mL ([MDS-6](#))

MDS-SF3B1
(low blasts)
No del(5q)
± other
cytogenetic
abnormalities
with ring
sideroblasts
(RS) $\geq 15\%$ (or
RS $\geq 5\%$ with
an SF3B1
mutation)

Preferred
Luspatercept-aamt^{ll,mm}
(category 1)

Other Recommended
Imetelstatⁿⁿ (if
serum EPO > 500
mU/mL [ineligible
for ESAs])

No del(5q) ± other cytogenetic
abnormalities with RS $< 15\%$
(or RS $< 5\%$ with an SF3B1
mutation)

→ [MDS-6](#)

Preferred
Imetelstat (category 1)ⁿⁿ

Other Recommended
Epoetin alfa^{kk} ±
granulocyte colony-
stimulating factor
(G-CSF)^{qq}
or
Darbepoetin alfa^{kk} ±
G-CSF^{qq}

Preferred
Imetelstat^{tr} (if not
previously used)
or
Luspatercept-aamt
(category 1) (if not
previously used)

Other Recommended
Consider lenalidomide^{jj}

No response
to imetelstat^{oo},
or ESAs ±
G-CSF^{pp} or
relapse^{ee}

See Serum
EPO > 500 mU/
mL ([MDS-6](#))

Other Recommended
Ivosidenib
(if mIDH1) or
Olutasidenib
(if mIDH1)
(category 2B)

Note: All recommendations are category 2A unless otherwise indicated.

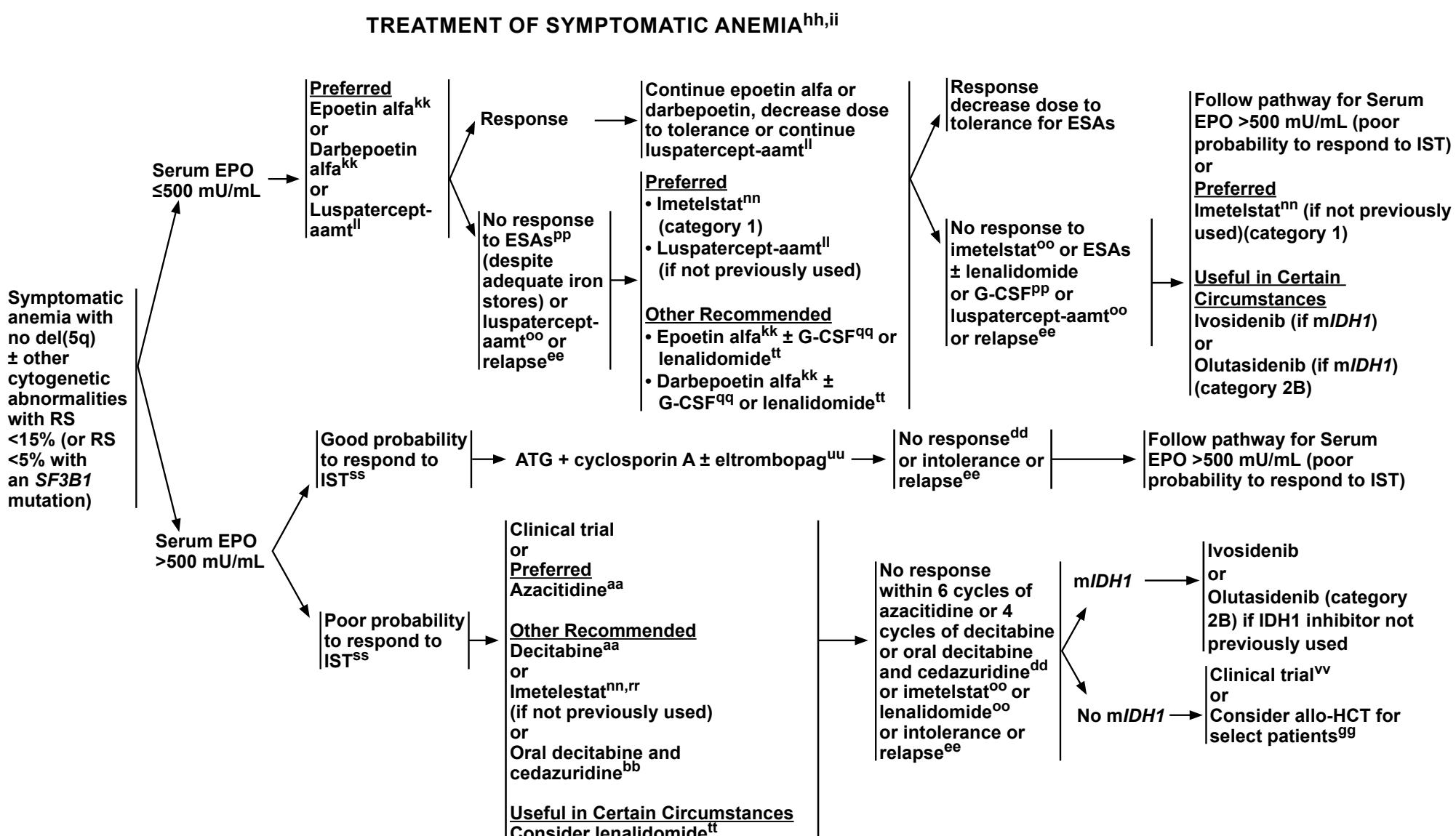
[Footnotes on MDS-6A](#)



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MANAGEMENT OF LOWER-RISK DISEASE (IPSS-R VERY-LOW-, LOW-, INTERMEDIATE-RISK DISEASE)^{w,x,y}



Note: All recommendations are category 2A unless otherwise indicated.

[Footnotes on MDS-6A](#)



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

FOOTNOTES FOR MDS-5 AND MDS-6

^w Presence of comorbidities should also be considered for evaluation of prognosis (see *Comorbidity Indices* in the [Discussion](#)).

^x Given its more accurate risk stratification, the IPSS-R categorization is preferred although the other systems also have good value. IPSS-R Intermediate-Risk MDS may be managed as lower risk if their score is ≤ 3.5 vs. higher risk if their score is > 3.5 . Pfeilstöcker M, et al. Blood 2016;128:902-910.

^y If the disease is initially managed as lower risk but fails to respond, move to higher risk management strategies.

^z See [Supportive Care \(MDS-8\)](#).

^{aa} Some studies have demonstrated clinical benefit with low doses of azacitidine or decitabine for lower-risk MDS. Sasaki K, et al. NEJM Evid 2022;EVIDoaa2200034.

^{bb} Oral decitabine and cedazuridine (DEC-C) could be a substitution for intravenous decitabine in patients with IPSS Intermediate-1 and above. Garcia-Manero G, et al. Lancet Haematol 2024;11:e15-e26.

^{dd} Treatment failure would be considered if no response within 3–6 months. Response should be evaluated based on IWG criteria: Cheson BD, et al. Blood 2006;108:419-425; Platzbecker U, et al. Blood 2019;133:1020-1030.

^{ee} Reevaluation with bone marrow and/or molecular testing is recommended.

^{gg} Patients with IPSS Intermediate-1, IPSS-R Intermediate, and WPSS Intermediate-Risk MDS with severe cytopenias would also be considered candidates for HCT. Matched sibling, unrelated donor, haploidentical donor, or cord blood donor, including standard and reduced-intensity preparative approaches, may be considered.

^{hh} Target hemoglobin range 10 to 12 g/dL; not to exceed 12 g/dL.

ⁱⁱ An FDA-approved biosimilar is an appropriate substitute for any recommended systemic biologic therapy in the NCCN Guidelines.

^{jj} Recommended lenalidomide initial dose is: 10 mg/day for 21 out of 28 days or 28 days monthly for 2–4 months to assess response ([Discussion](#)). Use caution for patients with low platelet and neutrophil counts; consider modifying lenalidomide dose. Sekeres MA, et al. J Clin Oncol 2008;26:5943-5949. Patients with monosomy 7 are an exception and should be treated in the higher prognostic risk category ([MDS-7](#)). Lenalidomide exposure has been associated with a selective expansion of TP53-mutated clones (Sperling AS, et al. Blood 2022;140:1753-1763). Additional consideration for and/or closer monitoring of particular patients is warranted.

^{kk} Dosing is 40,000–60,000 U 1–2 times per week subcutaneously (SC) for epoetin alfa and 150–300 mcg every other week SC for darbepoetin alfa. For lack of response, escalate the dose. At some institutions, darbepoetin alfa has been administered using doses up to 500 mcg every other week.

^{ll} Data have demonstrated the effectiveness of luspatercept for treating the anemia of patients with ring sideroblastic lower-risk MDS. Fenaux P, et al. N Engl J Med 2020;382:140-151. Data have emerged for patients with non-sideroblastic lower-risk MDS with anemia indicating similar but more prolonged responses with luspatercept compared to ESAs (Platzbecker U, et al. Lancet 2023;402:373-385). The starting dose of luspatercept-aamt is 1 mg/kg every 3 weeks, which may be increased to 1.33 mg/kg every 3 weeks if not RBC transfusion-free after at least two consecutive doses (6 weeks) at the 1 mg/kg starting dose. The dose may be further increased to 1.75 mg/kg every 3 weeks if not RBC transfusion-free after at least 2 consecutive doses (6 weeks) at the 1.33 mg/kg dose.

^{mm} Consider epoetin alfa or darbepoetin alfa if serum EPO ≤ 200 mU/mL.

ⁿⁿ Initial dosing is 7.1 mg/kg IV monthly with potential dose decrements since frequent transient thrombocytopenia and neutropenia may occur. Starting platelet and neutrophil levels should be $\geq 75,000$ and ≥ 1500 , respectively (Platzbecker U, et al. Lancet 2024;403:249-260).

^{oo} Lack of ≥ 1.5 gm/dL rise in hemoglobin or lack of a decrease in RBC transfusion requirement by 3 to 6 months of treatment.

^{pp} Lack of ≥ 1.5 gm/dL rise in hemoglobin or lack of a decrease in RBC transfusion requirement by 6 to 8 weeks of treatment.

^{qq} Dosing is 1–2 mcg/kg 1–2 times per week SC for G-CSF.

^{rr} This does not apply to patients with MDS-5q, since this patient population was not studied.

^{ss} Patients with a good probability to respond to IST are generally ≤ 60 y and with $\leq 5\%$ marrow blasts, or those with hypocellular marrows, PNH clone positivity, or STAT3-mutant cytotoxic T-cell clones, whereas patients with a poor probability to respond to IST lack these features.

^{tt} Lenalidomide 10 mg daily if absolute neutrophil count > 0.5 , platelets $> 50,000$; Toma A, et al. Leukemia 2016;30:897-905.

^{uu} ATG may be omitted when clinically indicated.

^{vv} Emerging data are demonstrating effectiveness of enasidenib for patients with MDS with IDH2 mutations (Medeiros BC, et al. Leukemia 2017;31:272-281).

Note: All recommendations are category 2A unless otherwise indicated.

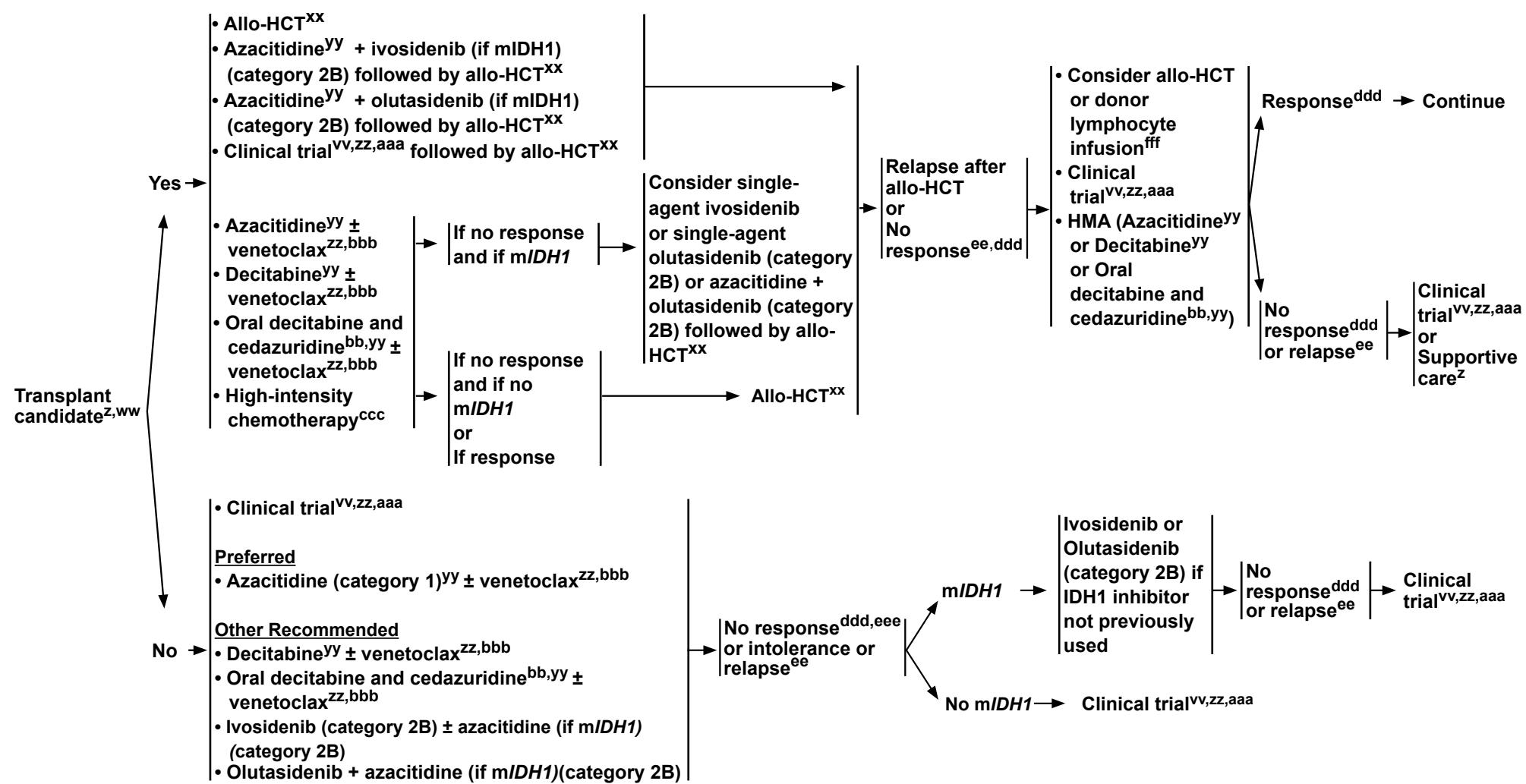


NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MANAGEMENT OF HIGHER-RISK DISEASE (IPSS-R INTERMEDIATE-, HIGH-, VERY-HIGH-RISK DISEASE)^{w,x}

TREATMENT



Note: All recommendations are category 2A unless otherwise indicated.

[Footnotes on MDS-7A](#)



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Myelodysplastic Syndromes

FOOTNOTES FOR MDS-7

w Presence of comorbidities should also be considered for evaluation of prognosis (see Comorbidity Indices in the [Discussion](#)).

x Given its more accurate risk stratification, the IPSS-R categorization is preferred although the other systems also have good value. IPSS-R Intermediate-Risk MDS may be managed as lower risk if their score is ≤ 3.5 vs. higher risk if their score is > 3.5 . Pfeilstöcker M, et al. Blood 2016;128:902-910.

z See [Supportive Care \(MDS-8\)](#).

bb Oral decitabine and cedazuridine (DEC-C) could be a substitution for intravenous decitabine in patients with IPSS Intermediate-1 and above. Garcia-Manero G, et al. Lancet Haematol 2024;11:e15-e26.

ee Reevaluation with bone marrow and/or molecular testing is recommended.

vv Emerging data are demonstrating effectiveness of enasidenib for patients with MDS with IDH2 mutations (Medeiros BC, et al. Leukemia 2017;31:272-281).

ww Based on age (including up to at least 75 y), performance status, major comorbid conditions, psychosocial status, patient preference, and availability of caregiver, patients may be taken immediately to transplant or bridging therapy can be used to decrease marrow blasts to an acceptable level prior to transplant. Nakamura R, et al. J Clin Oncol 2021;39:3328-3339.

xx Allogeneic HCT from the most suitable donor (ie, HLA-matched sibling or unrelated donor, HLA-haploidentical family member or cord blood). Early referral for transplant evaluation is recommended to allow moving to transplant efficiently. Pre-transplant debulking therapy to reduce marrow blasts to $< 5\%$ with the goal of reducing post-transplant relapse (see footnote yy and [Discussion](#)) is recommended, although the optimum strategy (ie, azacitidine, decitabine, induction-type chemotherapy) has not been determined. To reduce the disease burden pre-transplant is particularly important in patients who will receive a reduced-intensity conditioning regimen (Festuccia M, et al. Biol Blood Marrow Transplant 2016;22:1227-1233). At some centers, failure to achieve $< 5\%$ blasts with cytoreduction should not preclude patients from proceeding to transplant, as these patients appeared to derive survival benefit from transplant (Nakamura R, et al. J Clin Oncol 2021;39:3328-3339; Schroeder T, et al. Biol Blood Marrow Transplant 2019;25:1550-1559). Strategies for patients with specific mutations are under investigation. Patients with TP53 mutations, particularly biallelic, have a poor prognosis even with transplantation. These cases should be discussed with a transplant physician and patients should be enrolled in a clinical trial whenever possible.

yy Azacitidine, decitabine, or oral decitabine and cedazuridine should be continued for at least 4–6 cycles to assess response to these agents. In patients who have clinical benefit, continue treatment with the HMA as maintenance therapy. While the response rates are similar for both drugs, survival benefit from phase III randomized trials is reported for azacitidine and not for decitabine.

zz Some emerging data have shown efficacy of novel agents, including venetoclax in combination with HMAs or targeted IDH1/2 inhibitors for cytoreduction for patients with high-risk MDS (DiNardo C, et al. N Engl J Med 2018;378:2386-2398) who have HMA-refractory disease. When used as cytoreduction for MDS in combination with HMA, venetoclax has been effectively given in monthly courses of 14 days (Garcia JS, et al. Blood 2023;142:Abstract 319). Emerging data have also shown utility of olutasidenib for treating patients with IDH1 mutations (Cortes J, et al. Blood 2023;142:Abstract 1872). Repeat of marrow evaluation after 1–2 cycles is important to clarify recovery of hematopoiesis and potential requirement for further therapy.

aaa A 20% blast cut-off for AML evolving out of MDS (AML-MDS) and MDS-EB2 may be arbitrary in some clinical scenarios. AML-style therapies may be considered for appropriate patients with MDS-EB2, especially at younger ages of presentation. Furthermore, a diagnosis of AML may be made with less than 20% in patients with certain cytogenetic abnormalities per ICC (see [NCCN Guidelines for Acute Myeloid Leukemia](#)). Some clinical trials designed for high-grade MDS may allow enrollment of patients with AML-MDS (Estey E, et al. Blood 2022;139:323-332, DiNardo CD, et al. Cancer 2022;128:1568-1570). Per recent communications, some patients with higher risk disease with WHO 2022 MDS-IB2 and ICC MDS/AML could be considered for AML-type therapy (Khoury JD, et al. Leukemia 2022;36:1703-1719; Arber DA, et al. Blood 2022;140:1200-1228).

bbb The addition of venetoclax is based on patient status and tolerance.

ccc High-intensity chemotherapy: Clinical trials with investigational therapy (preferred); or standard induction therapy if investigational protocol is unavailable or if it is used as a bridge to HCT.

ddd Treatment failure would be considered if no response within 3–6 months.

Response should be evaluated based on IWG criteria: Cheson BD, et al. Blood 2006;108:419-425; Zeidan AM, et al. Blood 2023;141:2047-2061.

eee For HMAs, if no response within 6 cycles of azacitidine or 4 cycles of decitabine or oral decitabine and cedazuridine.

fff Consider second transplant or donor lymphocyte infusion immuno-based therapy for appropriate patients who had a prolonged remission after first transplant.

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

SUPPORTIVE CARE^{ii,ggg}

• Clinical monitoring

► **Psychosocial support** (see [NCCN Guidelines for Survivorship](#))

► **Quality-of-life assessment**

► **Transfusions^{hhh}:**

◊ RBC transfusions (CMV-safe) are recommended for symptomatic anemia, and platelet transfusions are recommended for thrombocytopenic bleeding. However, they are generally not used routinely in patients with thrombocytopenia in the absence of bleeding unless platelet count <10,000/mcL. Irradiated products are suggested for transplant candidates.

► Antibiotics are recommended for bacterial infections, and prophylaxis may be considered when starting patients on therapy, consistent with local hospital guidelines.

• Aminocaproic acid or other antifibrinolytic agents may be considered for bleeding refractory to platelet transfusions or profound thrombocytopenia.

• Iron chelationⁱⁱⁱ:

► If >20 to 30 RBC transfusions have been received, consider daily chelation with deferoxamine SC or deferasirox^{jjj} orally to decrease iron overload, particularly for patients who have lower-risk MDS or who are potential transplant candidates (LOW/INT-1). For patients with serum ferritin levels >2500 ng/mL, aim to decrease ferritin levels to <1000 ng/mL ([Discussion](#)). Patients with low creatinine clearance (<40 mL/min) should not be treated with deferasirox or deferoxamine.

• Cytokines:

► **ESAs:** See [Anemia Pathway \(MDS-5\)](#)

◊ ESAs refer to the following agents: epoetin alfa and darbopoietin alfa.

► **G-CSF:**

◊ G-CSF refers to the following agents: filgrastim and tbo-filgrastim. Not recommended for routine infection prophylaxis.

◊ Consider use in patients with neutropenia with recurrent or resistant infections.

◊ Combine with ESAs for anemia when indicated. See [Anemia Pathway \(MDS-5\)](#).

◊ Platelet count should be monitored.

• Clinically significant thrombocytopenia:

► In patients with lower-risk MDS who have severe or life-threatening thrombocytopenia, consider treatment with a thrombopoietin-receptor agonist.^{kkk}

• Post-transplant:

► Patients should receive antimicrobial prophylaxis at least as long as they are on IST.

► Detailed recommendations are provided in the Guidelines generated by the American Society for Transplantation and Cellular Therapy (ASTCT, formerly ASBMT). See [NCCN Guidelines for Hematopoietic Cell Transplantation \(HCT\)](#).

ⁱⁱ An FDA-approved biosimilar is an appropriate substitute for any recommended systemic biologic therapy in the NCCN Guidelines.

^{ggg} See [NCCN Guidelines for Supportive Care](#).

^{hhh} Avoid transfusions for arbitrary hemoglobin thresholds in the absence of symptoms of active coronary disease, heart failure, or stroke. In situations where transfusions are necessary, transfuse the minimum units necessary to relieve symptoms of anemia or to return the patient to a safe hemoglobin level. Hicks L, et al. Blood 2013;122:3879-3883.

ⁱⁱⁱ Hoeks M, et al. Haematologica 2020;105:640-651; Yang S, et al. Br J Haematol 2022;197:e9-e11; Angelucci E, et al. Ann Intern Med 2020;172:513-522.

^{jjj} Ophthalmic and auditory tests are recommended annually when using deferasirox. Monitor serum creatinine regularly upon starting deferasirox.

^{kkk} Giagounidis A, et al. Cancer 2014;120:1838-1846. Platzbecker U, et al. Lancet Haematol 2015;2:e417-e426. Oliva EN, et al. Lancet Haematol 2017;4:e127-e136.

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

PATHOLOGIC-MORPHOLOGIC CLASSIFICATIONS OF MYELODYSPLASTIC NEOPLASMS 2023^{a,b}

Transition from Clinically Based Classifications to New Systems Including Genomic Features in 2022

WHO 2016 ¹	WHO 2022 ²	ICC 2022 ³	Bone Marrow Blasts
	MDS, genetically defined		
MDS-del(5q)	MDS-5q ^d	MDS-del(5q) ^d	<5%
MDS-RS	MDS-SF3B1 ^e	MDS-SF3B1 ^{e,h}	<5%
—	MDS-biTP53 ^f	Myeloid neoplasms with mTP53 ⁱ	<20%
	MDS, morphologically defined		
MDS-SLD, MDS-MLD	MDS-LB	MDS-NOS ^j	<5%
—	MDS-hypoplastic ^g	—	<5%
MDS-EB1	MDS-IB1	MDS-EB	5%–9%
MDS-EB2	MDS-IB2 ^c	MDS/AML ^c	10%–19%
—	MDS with fibrosis	—	5%–19%
AML ^c	AML^c	AML ^c	≥20% ^c

^a Defined by dysplasia (≥10% for any hematopoietic lineage) and cytopenia(s). In general, clinical evidence should indicate that the blood count abnormality is chronic in duration (typically ≥2 to 4 months) and not explained by drug, toxin, or comorbid condition.

^b This table compares specific aspects of the WHO 2016, WHO 2022, and ICC MDS classifications for definitions only. Care should be taken in the clinic as classifications alone do not imply therapeutic choice. AML remains a separate entity (see [NCCN Guidelines for Acute Myeloid Leukemia](#)) with therapeutic options distinct from MDS or MDS/AML in the majority of patients without rational prognostication until interventions have been rigorously studied in this entity.

^c ≥20% marrow blasts or those with AML-defining molecular abnormalities. See [MDS-A 4 of 5](#).

^d Sole genetic abnormality (or allowable 1 other cytogenetic lesion other than chromosome 7 abnormality).

^e ≥15% RS only if molecular analysis not available; no del(5q), multiTP53, -7/del(7q), abn(3q), or complex cytogenetics.

^f WHO: Biallelic mutation status determined by VAF ≥50%, >1 distinct mutations, TP53 locus.

^g ≤25% bone marrow cellularity, age-adjusted.

^h No RUNX1 mutation.

ⁱ ICC: Biallelic mutation status determined by VAF >50%, >1 distinct mutations, TP53 locus loss of heterozygosity (LOH); single TP53 mutation and complex karyotype (presumptive).

^j With -7/del(7q) or complex.

[References on MDS-A 5 of 5](#)

Note: All recommendations are category 2A unless otherwise indicated.

MDS-A
1 OF 5



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

CLINICAL PRINCIPLES OF MYELODYSPLASTIC/MYELOPROLIFERATIVE NEOPLASM (MDS/MPN) OVERLAP NEOPLASMS

- Clinical, morphologic, and mutational diagnostic features and treatment approaches for the various nosologic MDS/MPN subtypes are shown in the table on [MDS-A \(3 of 5\)](#).
- Prognostic classification systems have been developed for patients with CMML with features similar to those for MDS. Proliferative CMML (white blood cell [WBC] count >12,000/mm³) has a worse prognosis than the dysplastic subtype.
- Mutational findings are listed in the table on [MDS-A \(3 of 5\)](#) with a major consistency in CMML, indicating ASXL1 as being an adverse prognostic feature.
- Therapeutic approaches in CMML have generally been the model for treating the other MDS/MPN, with HMA ± venetoclax treatment for patients with intermediate- and higher-risk disease, and using these agents as a bridge to allogeneic HCT for those patients deemed to be transplant-eligible. The trajectory of disease progression may differ in the disparate clinical entities based on their underlying molecular features. Thus, expectant clinical monitoring is needed to assess potential change in patient's clinical status, needing altered management of the disorder.
- Transplant eligibility principles include patients having fit performance status, their age, and having a donor.
- Treatment response criteria for CMML have been developed by an international consortium of investigators.
- Patients with CMML may have systemic mastocytosis with associated hematologic neoplasm (SM-AHN) with a *KIT* D816V mutation in the neoplastic monocytes and mast cells. These patients may have marked hepatosplenomegaly, mast cell activation symptoms, or cutaneous lesions with elevated serum tryptase levels. The mastocytosis may be responsive to midostaurin treatment. Each disease should be treated independently depending on its severity, being aware of drug-drug interactions.
 - ▶ Next-generation sequencing (NGS) has low sensitivity for *KIT* D816V mutation, and allele-specific PCR is more sensitive and recommended in patients with high clinical suspicion of mast cell disease. Arock M, Sotlar K, Akin C, et al. *KIT* mutation analysis in mast cell neoplasms: recommendations of the European Competence Network on Mastocytosis. *Leukemia* 2015;29:1223-1232. See [NCCN Guidelines for Systemic Mastocytosis](#).
 - ▶ cKIT-directed therapy should be considered for systemic mastocytosis (Bose P, Verstovsek S. Avapritinib for systemic mastocytosis. *Expert Rev Hematol* 2021;14:687-696).
- About 10%–20% of patients with blastic plasmacytoid dendritic cell neoplasm (BPDCN) skin lesions are associated with or develop into other myeloid neoplasms, including CMML, MDS, or AML (Facchetti F, et al. Blastic plasmacytoid dendritic cell neoplasm. In: Swerdlow SH, et al. Revised 4th ed. Lyon: IARC Press; 2017:173-177). Therefore, an accurate pathologic diagnosis is important for patients to receive the best care. Tagraxofusp has been demonstrated to be a potentially useful therapy for these patients (Pemmaraju N, Lane AA, Sweet KL, et al. Tagraxofusp in blastic plasmacytoid dendritic-cell neoplasm. *N Engl J Med* 2019;380:1628-1637).

Note: All recommendations are category 2A unless otherwise indicated.

MDS-A
2 OF 5



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MDS/MPN CLASSIFICATION

WHO 2016 ¹	WHO 2022 ²	ICC ³	Features	Frequent Mutations	Treatment
Chronic myelomonocytic leukemia (CMML)	CMML-1 ^k CMML-2 ^l	CMML-myelodysplastic (CMML-MD) ^m CMML-myeloproliferative (CMML-MP) ^m	≥0.5 absolute monocyte count (AMC) ≥10% monocytes Clonality ^p	<i>TET2</i> , <i>SRSF2</i> , <i>ASXL1</i> , <i>RUNX1</i> , <i>NRAS</i> , <i>CBL</i> ^{4,5}	CMML-1: Consider HMA ^s or hydroxyurea ^{u,v,13-23} CMML-2: HMA ^{s,w} ± venetoclax ^X and/or allogeneic HCT ^{t,u,v,13-26}
Atypical chronic myeloid leukemia (aCML) (BCR::ABL negative)	MDS/MPN and neutrophilia	aCML	WBC ≥13K, dysplastic granulocytosis, ≥10% granulocytic precursor cells ^q mSETBP1 ± mASXL1	<i>SETBP1</i> , <i>ETNK1</i> ⁶ , BCR::ABL1 negative	• Consider HMA ^s and/or ruxolitinib ^y and/or allogeneic HCT ^{v,27,28}
MDS/MPN with ring sideroblasts (RS) and thrombocytosis (T)	MDS/MPN with mSF3B1 and thrombocytosis	MDS/MPN-T-SF3B1 ⁿ MDS/MPN-RS-T, NOS	Platelets ≥450K	<i>SF3B1</i> , <i>JAK2</i> ^{7,8} <i>MPL</i> , <i>CALR</i>	• Consider HMA ^s and/or lenalidomide ^{v,29} or • Consider luspatercept-aamt ^{v,z,30}
MDS/MPN unclassifiable (MDS/MPN-U)	MDS/MPN not otherwise specified (NOS)	MDS/MPN NOS	Platelets ≥450K or WBC ≥13K	<i>TET2</i> , <i>NRAS</i> , <i>RUNX1</i> , <i>CBL</i> , <i>SETBP1</i> , <i>ASXL1</i> ⁹	• Consider HMA ^s and/or allogeneic HCT ^v
—	—	MDS/MPN with i(17q) ^o	WBC ≥13K, dysgranulopoiesis	<i>SETBP1</i> , <i>SRSF2</i> ¹⁰	Allogeneic HCT ^{v,10,31}
Juvenile myelomonocytic leukemia (JMML)	JMML (now MPN)	Pediatric disorder and/or germline mutation-associated disorders	>90% RAS pathway activation abnormality ^r	<i>PTPN11</i> , <i>NF1</i> , <i>NKRAS</i> , <i>CBL</i> , <i>SETBP1</i> , <i>JAK3</i> ^{11,12}	Allogeneic HCT ^v

^t Patients with CMML may have disease that responds to ruxolitinib for symptomatic disease. Padron E, et al. Clin Cancer Res 2016;22:3746-3754. Padron E, et al. Blood 2022;140:1101-1103. Consider exclusion of other abnormalities associated with myeloid/lymphoid neoplasms with eosinophilia and tyrosine kinase gene fusions (ie, *PDGFRA/PDGFRB-r*, *FGFR1-r*, or *PCM1::JAK2*; using FISH or RNA sequencing) to establish diagnosis of CMML. Patients with a t(5;12) translocation associated with the *ETV6::PDGFRβ* fusion gene may have disease that responds to imatinib mesylate. See [NCCN Guidelines for Myeloid/Lymphoid Neoplasms with Eosinophilia and Tyrosine Kinase Gene Fusions](#). Patients with CMML may have associated systemic mastocytosis (SM-AHN) and *KIT D816V* mutation responsive to midostaurin. Molecular testing with a high-sensitivity PCR is required to detect *KIT D816V*.

^u Avapritinib was recently approved by the FDA in SM-AHN including CMML. DeAngelo DJ, et al. Nat Med 2021;27:2183-2191. Gotlib J, et al. Nat Med 2021;27:2192-2199.

^v Hydroxyurea may be helpful in decreasing excessive leukocytosis or thrombocytosis (Itzykson R, et al. Blood 2020;136:53-54).

^w Ruxolitinib may be added to HMAs for symptom management or splenomegaly.

^x In non-transplant candidates, the risk of cytopenias with the addition of venetoclax should be carefully considered.

^y Rare patients with *CSF3R* or *JAK2* mutations may have disease that responds to ruxolitinib therapy due to their JAK-STAT pathway activation.

^z Luspatercept-aamt is an option for the treatment of anemia.

^k <10% bone marrow blasts or blast equivalents.

^l 10% to <20% bone marrow blasts or blast equivalents.

^m CMML-MD=WBC ≤13K, CMML-MP=WBC >13K.

ⁿ VAF >10%.

^o Provisional.

^p 80%-90% with ≥1 mutation in *SRSF2*, *TET2*, and/or *ASXL1*. Substantial frequency of *SETBP1*, *NRAS/KRAS*, *RUNX1*, *CBL*, and *EZH2* mutations.

^q <10% eosinophilia.

^r Canonical RAS pathway mutations in *NRAS*, *KRAS*, *PTPN11*, *NF1*, *CBL*, or RAS-related genes in >95% patients; no *KMT2A* rearrangement or -7 cytogenetic abnormality.

^s Oral decitabine and cedazuridine (DEC-C) could be a substitution for intravenous decitabine in patients with IPSS Intermediate-1 and above. Garcia-Manero G, et al. Blood 2020;136:674-683.

Note: All recommendations are category 2A unless otherwise indicated.

References on MDS-A 5 of 5
MDS-A 3 OF 5



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENETIC/CYTOGENETIC ABNORMALITIES IN AML AND MDS

AML-DEFINING GENETIC ABNORMALITIES: WHO 2022 AND ICC^{2,3,32}

AML	Acute promyelocytic leukemia (APL)
<ul style="list-style-type: none"> • t(8;21)(q22;q22.1)/RUNX1::RUNX1T1 • inv(16)(p13.1q22) or t(16;16)(p13.1;q22)/CBFB::MYH11 • t(9;11)(p21.3;q23.3)/MLLT3::KMT2A • Other KMT2A rearrangements • t(6;9)(p22.3;q34.1)/DEK::NUP214 • inv(3)(q21.3q26.2) or t(3;3)(q21.3;q26.2)/GATA2; MECOM(EVI1) • Other MECOM rearrangements • Mutated NPM1 • CEBPA (WHO), in-frame bZIP CEBPA mutations (ICC) • RBM15::MRTFA fusion • NUP98 rearrangement 	<ul style="list-style-type: none"> • t(15;17)(q24.1;q21.2)/PML::RARA • Other RARA rearrangements

COMMON CYTOGENETIC ABNORMALITIES IN MDS^{aa,bb,*}

Unbalanced Abnormalities	Balanced Abnormalities
<ul style="list-style-type: none"> • -7 or del(7q)* • -5 or del(5q)* • i(17q) or t(17p) * • -13 or del(13q) • del(11q) • del(12p) or t(12p) • del(9q) • idic(X)(q13) • del(20q) • +8* • -Y 	<ul style="list-style-type: none"> • t(11;16)(q23;p13.3) • t(3;21)(q26.2;q22.1) • t(1;3)(p36.3;q21.1) • t(2;11)(p21;q23) • inv(3)(q21q26.2) • t(6;9)(p23;q34)

^{aa} Both the IPSS and IPSS-R rely heavily on cytogenetics; if a proper metaphase karyotype is non-informative/cannot be performed, the minimum recommended panel for FISH consists of abnormalities noted with an asterisk. Of note, there is also FISH for TP53.

^{bb} Both WHO and ICC recommend that without morphologic dysplasia, clonal cytogenetic abnormalities like loss of chromosome 13 or del(13q), del(9q), etc., which were considered as presumptive MDS, should not be used to diagnose MDS but handled in the same way as CHIP mutations.

* Adapted with permission from Vardiman JW, Thiele J, Arber DA, et al. The 2008 revision of the World Health Organization (WHO) classification of myeloid neoplasms and acute leukemia: rationale and important changes. Blood 2009;114:937-951.

[References on MDS-A 5 of 5](#)

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NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

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Note: All recommendations are category 2A unless otherwise indicated.



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Myelodysplastic Syndromes

[NCCN Guidelines Index](#)

[Table of Contents](#)

[Discussion](#)

PROGNOSTIC SCORING SYSTEMS

INTERNATIONAL PROGNOSTIC SCORING SYSTEM (IPSS)^{a,1}

Survival and AML Evolution					
	Score Value				
Prognostic variable	0	0.5	1.0	1.5	2.0
Marrow blasts (%) ^b	<5	5–10	—	11–20	21–30
Karyotype ^c	Good	Intermediate	Poor	—	—
Cytopenia ^d	0/1	2/3	—	—	—

PROGNOSIS ACCORDING TO IPSS RISK SCORE¹

IPSS Risk Category (% IPSS pop.)	Overall Score	Median Survival (y) in the Absence of Therapy	25% AML Progression (y) in the Absence of Therapy
LOW (33)	0	5.7	9.4
INT-1 (38)	0.5–1.0	3.5	3.3
INT-2 (22)	1.5–2.0	1.1	1.1
HIGH (7)	≥2.5	0.4	0.2

For IPSS: Low/Intermediate-1, see [MDS-4 through MDS-6](#)

For IPSS: Intermediate-2/High, see [MDS-7](#)

^a IPSS should be used for initial prognostic and planning purposes. WPSS permits dynamic estimation of prognosis at multiple time points during the course of MDS.

^b Patients with 20%–29% blasts may be considered to have MDS (FAB) or AML (WHO).

^c Cytogenetics: Good = normal, -Y alone, del(5q) alone, del(20q) alone; Poor = complex (≥3 abnormalities) or chromosome 7 anomalies; Intermediate = other abnormalities. [This excludes karyotypes t(8;21), inv16, and t(15;17), which are considered to be AML and not MDS.]

^d Cytopenias: neutrophil count <1800/mcL, platelets <100,000/mcL, Hb <10 g/dL.

^e Cytogenetic risks: Very good = -Y, del(11q); Good = normal, del(5q), del(12p), del(20q), double including del(5q); Intermediate = del(7q), +8, +19, i(17q), any other single or double independent clones; Poor = -7, inv(3)/t(3q)/del(3q), double including -7/del(7q), complex: 3 abnormalities; Very poor = complex: >3 abnormalities.

REVISED INTERNATIONAL PROGNOSTIC SCORING SYSTEM (IPSS-R)²

Prognostic variable	Score Value						
	0	0.5	1	1.5	2	3	4
Cytogenetic ^e	Very good	—	Good	—	Intermediate	Poor	Very poor
Marrow blasts (%)	≤2	—	>2–<5	—	5–10	>10	—
Hemoglobin	≥10	—	8–<10	<8	—	—	—
Platelets	≥100	50–<100	<50	—	—	—	—
ANC	≥0.8	<0.8	—	—	—	—	—

PROGNOSIS ACCORDING TO IPSS-R RISK SCORE²

IPSS-R Risk Category (% IPSS-R pop.)	Overall Score	Median Survival (y) in the Absence of Therapy	25% AML Progression (y) in the Absence of Therapy
VERY LOW (19)	≤1.5	8.8	Not reached
LOW (38)	>1.5–≤3.0	5.3	10.8
INT ³ (20)	>3.0–≤4.5	3	3.2
HIGH (13)	>4.5–≤6.0	1.6	1.4
VERY HIGH (10)	>6.0	0.8	0.7

For IPSS-R: Very Low/Low/Intermediate, see [MDS-4 through MDS-6](#)

For IPSS-R: Intermediate/High/Very High, see [MDS-7](#)

¹ Adapted with permission from: Greenberg PL, Cox C, LeBeau M, et al. International scoring system for evaluating prognosis in myelodysplastic syndromes. Blood 1997;89:2079–2088; Erratum. Blood 1998;91:1100.

² Adapted with permission from: Greenberg PL, Tuechler H, Schanz J, et al. Revised international prognostic scoring system for myelodysplastic syndromes. Blood 2012;120:2454–2465. Websites for accessing the IPSS-R calculator tool: <https://www.mds-foundation.org/professional/resources/prognosis-calculators>. A mobile app for the calculator tool is also available.

[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.

MDS-B
1 OF 4



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

PROGNOSTIC SCORING SYSTEMS

WHO-BASED PROGNOSTIC SCORING SYSTEM (WPSS)^{3,4}

Variable	Variable Scores			
	0	1	2	3
WHO category	RCUD, RARS, MDS with isolated del(5q)	RCMD	RAEB-1	RAEB-2
Karyotype ^c	Good	Intermediate	Poor	—
Severe anemia (hemoglobin <9 g/dL in males or <8 g/dL in females)	Absent	Present	—	—

PROGNOSIS ACCORDING TO WPSS RISK SCORE^{3,4}

WPSS Risk	Sum of Individual Variable Scores	Median Survival (y) from Diagnosis	Median Time (y) to AML Progression from Diagnosis
Very Low	0	11.6	NR
Low	1	9.3	14.7
Intermediate	2	5.7	7.8
High	3–4	1.8	1.8
Very High	5–6	1.1	1.0

For WPSS: Very Low, Low, Intermediate, see [MDS-4](#) through [MDS-6](#)

For WPSS: High, Very High, see [MDS-7](#)

^c Cytogenetics: Good = normal, -Y alone, del(5q) alone, del(20q) alone; Poor = complex (≥ 3 abnormalities) or chromosome 7 anomalies; Intermediate = other abnormalities. [This excludes karyotypes t(8;21), inv16, and t(15;17), which are considered to be AML and not MDS.]

³ Adapted with permission from: Malcovati L, Della Porta MG, Strupp C, et al. Impact of the degree of anemia on the outcome of patients with myelodysplastic syndromes and its integration into the WHO classification-based Prognostic Scoring System (WPSS). Haematologica 2011;96:1433-1440.

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[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

PROGNOSTIC SCORING SYSTEMS

INTERNATIONAL PROGNOSTIC SCORING SYSTEM MOLECULAR (IPSS-M)^{f,5}

IPSS-M	Very Low VL	Low L	Moderate Low ML	Moderate High MH	High H	Very High VH
Patients, % (n = 2701)	14% (381)	33% (889)	11% (302)	11% (281)	14% (379)	17% (469)
Risk score	≤ -1.5	> -1.5 to -0.5	> -0.5 to 0	> 0 to 0.5	> 0.5 to 1.5	> 1.5
Hazard ratio^g (95% CI)	0.51 (0.39–0.67)	1.0 reference	1.5 (1.2–1.8)	2.5 (2.1–3.1)	3.7 (3.1–4.4)	7.1 (6.0–8.3)
Median LFS, y 25%–75% LFS range, y	9.7 5.0–17.4	5.9 2.6–12.0	4.5 1.6–6.9	2.3 0.91–4.7	1.5 0.80–2.8	0.76 0.33–1.5
Median OS, y 25%–75% OS range, y	10.6 5.1–7.4	6.0 3.0–12.8	4.6 2.0–7.4	2.8 1.2–5.5	1.7 1.0–3.4	1.0 (0.5–1.8)
AML-t by 1 y, % 2 y 4 y	0.0 1.2 2.8	1.7 3.4 5.1	4.9 8.8 11.4	9.5 14.0 18.9	14.3 21.2 29.2	28.2 38.6 42.8
Death w/o AML, by 1 y, % 2 y 4 y	2.2 7.0 15.9	8.5 16.2 29.5	12.0 19.8 33.6	18.0 31.1 51.1	19.3 39.8 54.2	30.6 45.6 51.3

Abbreviations: LFS, leukemia-free survival; OS, overall survival; AML-t, AML transformation

^f The IPSS-M may have a role in clinical decision-making but requires confirmatory evidence to help assess its efficacy.

^g Hazard ratio for risk of AML-t or death.

⁵ With permission from: Bernard E, Tuechler H, Greenberg PL, et al. Molecular International Prognosis Scoring System for Myelodysplastic Syndromes. NEJM Evid 2022;1:Evidoa2200008. IPSS-M Web calculator: <https://mds-risk-model.com>.

[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

PROGNOSTIC SCORING SYSTEMS

GENE MUTATIONS FOR THE IPSS-M PROGNOSTIC RISK SCHEMA⁵

Main Effect Genes (n=16) ^h	Residual Genes (Nres) (n=15)
<i>TP53</i> ^{multi}	<i>BCOR</i>
<i>MLL</i> ^{PTD}	<i>BCORL1</i>
<i>FLT3</i>	<i>CEBPA</i>
<i>SF3B1</i> ^{5q}	<i>ETNK1</i>
<i>NPM1</i>	<i>GATA2</i>
<i>RUNX1</i>	<i>GNB1</i>
<i>NRAS</i>	<i>IDH1</i>
<i>ETV6</i>	<i>NF1</i>
<i>IDH2</i>	<i>PHF6</i>
<i>CBL</i>	<i>PPM1D</i>
<i>EZH2</i>	<i>PRPF8</i>
<i>U2AF1</i>	<i>PTPN11</i>
<i>SRSF2</i>	<i>SETBP1</i>
<i>DNMT3A</i>	<i>STAG2</i>
<i>ASXL1</i>	<i>WT1</i>
<i>KRAS</i>	
<i>SF3B1</i> ^a	

SF3B1^{5q}, *SF3B1* mutation with isolated *del(5q)* or with one additional aberration excluding -7/*del(7q)*.

SF3B1^a, *SF3B1* mutation without co-mutations in *BCOR*, *BCORL1*, *RUNX1*, *NRAS*, *STAG2*, *SRSF2*, or *del(5q)*.

^h In statistically weighted order.

⁵ With permission from: Bernard E, Tuechler H, Greenberg PL, et al. Molecular International Prognosis Scoring System for Myelodysplastic Syndromes. NEJM Evid 2022;1:Evidoa2200008. IPSS-M Web calculator: <https://mds-risk-model.com>.

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NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENES FREQUENTLY SOMATICALLY MUTATED IN MDS^{a,b}

This table lists gene mutations likely to be somatic (acquired, not congenital) and disease-related and therefore presumptive evidence of MDS. Other mutations (not listed in the table below) in these genes can occur in MDS. Additionally, some of these mutations can occur in the context of aging and do not in isolation establish a diagnosis of MDS, nor does the absence of mutations in these genes exclude a diagnosis of MDS in the correct clinical context.

Mutated Gene ^c	Examples of Typical Somatic Mutation Types and Locations in Select MDS-Related Genes ^e	Overall Incidence	Clinical Significance
<i>TET2</i>	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u> <u>Missense</u> : any in codons 1134–1444 or 1842–1921	20%–25%	Associated with normal karyotypes. More frequent in CMML (40%–60%). Common in CHIP and CCUS.
<i>DNMT3A</i>	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u> <u>Missense</u> in codons G543, R635, A741, R736, H739, S770, M880, R882, W893, P904, A910	12%–18%	More frequent occurrence in AML, particularly R882 mutations. Common in CHIP and CCUS.
<i>ASXL1</i>	<u>Nonsense</u> or <u>Frameshift</u>	15%–25%	Independently associated with a poor prognosis in MDS and CMML. More frequent in CMML (40%–50%). Common in CHIP and CCUS.
<i>EZH2</i>	<u>Nonsense</u> or <u>Frameshift</u>	5%–10%	Independently associated with a poor prognosis in MDS and MDS/MPN. More frequent in CMML (12%).
<i>SF3B1</i>	<u>Missense</u> : E622, Y623, R625, N626, H662, T663, K666, K700E, I704, G740, G742, D781	20%–30%	Strongly associated with RS and more frequent in MDS-RS (80%). Independently associated with a more favorable prognosis.
<i>SRSF2</i>	<u>Missense</u> or <u>In-Frame Deletion</u> : involving codon P95	10%–15%	More frequent in CMML (40%) and associated with a poor prognosis.
<i>U2AF1</i>	<u>Missense</u> : S34, Q157	8%–12%	Associated with a poor prognosis.
<i>ZRSR2</i>	<u>Nonsense</u> or <u>Frameshift</u>	5%–10%	Associated with a poor prognosis.
<i>RUNX1^d</i>	<u>Nonsense</u> or <u>Frameshift</u>	10%–15%	Independently associated with a poor prognosis in MDS.
<i>TP53^d</i>	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u> <u>Missense</u> : any in codons except P47S and P72R	8%–12%	Independently associated with a poor prognosis. More frequent with complex karyotypes (50%) and del(5q) (15%–20%). May predict resistance or relapse to lenalidomide.
<i>STAG2</i>	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u>	5%–10%	Associated with a poor prognosis.
<i>NRAS^d</i>	<u>Missense</u> : G12, G13, Q61	5%–10%	Associated with a poor prognosis, particularly in patients predicted to have lower-risk MDS. More frequent in CMML and JMML (~15%).
<i>CBL^d</i>	<u>Missense</u> : any in codons 366–420	<5%	More frequent in CMML (10%–20%) and JMML (15%).
<i>NF1^d</i>	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u>	<5%	More frequent in CMML (5%–10%) and in JMML (30%) where it is often germline.

^a The specific mutations listed in this table are likely to be somatic if found in tumor material. Their absence in non-hematopoietic tissues would be required to prove that they are acquired. Known gene polymorphisms frequent in the population should be excluded from DNA sequencing results as they are likely germline variants and not evidence of clonal hematopoiesis.

^b There are microdeletions that would be missed by typical genetic sequencing or karyotype that affects some of the same genes that may be indicative of clonal hematopoiesis.

^c Somatic mutations in several MDS-associated genes (eg, *TET2*, *DNMT3A*, *TP53*) can occur in non-disease states and no gene mutation is diagnostic of MDS. Mutations in several genes can occur in neoplasms other than MDS, including lymphoid malignancies such as chronic lymphocytic leukemia (CLL) and acute lymphoblastic leukemia (ALL). Mutations should not be used as presumptive evidence of MDS when diagnostic criteria for MDS have not been met.

^d Constitutional (germline) mutations in these genes can occur and cause a hematopoietic phenotype. Mutations identified in testing blood or marrow for somatic mutations associated with MDS can identify constitutional (germline) mutations. Distinguishing constitutional from somatic mutations often requires sequencing DNA from a non-hematopoietic tissue in MDS.

^e Mutation type definitions: Nonsense – a mutation that changes an amino acid codon into a premature stop codon. Frameshift – the insertion or deletion of DNA base pairs that changes the amino acid reading frame. Missense – a mutation that changes one amino acid codon into another (eg, K700E indicates that the lysine [K] at codon 700 was mutated to a glutamic acid [E]). If no new amino acid is specified for a codon in the table, then it may be mutated into one of several possible amino acids (eg, R882 indicates that the arginine [R] at position 882 can be mutated in more than one way). Splice Site – a mutation that alters the first or second bases immediately before or after an exon.

[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENES FREQUENTLY SOMATICALLY MUTATED IN MDS^{a,b}

This table lists gene mutations likely to be somatic (acquired, not congenital) and MDS-related. Other mutations (not listed in the table below) in these genes can occur in MDS. Additionally, some of these mutations can occur in the context of aging and do not in isolation establish a diagnosis of MDS, nor does the absence of mutations in these genes exclude a diagnosis of MDS in the correct clinical context.

Mutated Gene ^c	Examples of Typical Somatic Mutation Types and Locations in Select MDS-Related Genes ^e	Overall Incidence	Clinical Significance
JAK2	<u>Missense</u> : V617F	<5%	More frequent in MDS/MPN-RS-T (50%); can occur in conjunction with SF3B1.
CALR	<u>Frameshift</u> : after codon 352	<5%	Observed in MDS/MPN-RS-T where it can occur in conjunction with SF3B1 mutations.
MPL	<u>Missense</u> : W515L/K	<5%	Observed in MDS/MPN-RS-T where it can occur in conjunction with SF3B1 mutations.
ETV6 ^d	<u>Nonsense</u> or <u>Frameshift</u>	<5%	Independently associated with a poor prognosis.
GATA2 ^d	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u> <u>Missense</u> : in codons 349–398		Associated with a poor prognosis.
DDX41 ^d	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u> <u>Missense</u> : in codon R525H		Constitutional (germline) mutations in this gene can occur.
IDH1	<u>Missense</u> : R132	<5%	More frequent in AML.
IDH2	<u>Missense</u> : R140Q, R172	<5%	More frequent in AML. Associated with a poor prognosis.
SETBP1	<u>Missense</u> : E858, T864, I865, D868, S869, G870	<5%	Associated with disease progression. More frequent in aCML (24%); CMML (5%–10%) and JMML (7%).
PHF6	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u>	<5%	More frequent in cases with excess blasts (EBs), but no association with survival.
BCOR	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u>	<5%	Associated with a poor prognosis. More frequent in CMML (5%–10%).
FLT3	<u>Internal Tandem Duplication</u> or <u>Missense</u> : in codon D835		Associated with a poor prognosis.
WT1	<u>Nonsense</u> or <u>Frameshift</u> or <u>Splice Site</u>		Associated with a poor prognosis.
NPM1	<u>Frameshift</u> : W288fs*12		Associated with a poor prognosis.
STAT3	<u>Missense</u> : any codons 584–674	<5%	Occurs in LGL associated with MDS; associated with immune bone marrow failure.
PPM1D	<u>Nonsense</u> or <u>Frameshift</u>	~5%	Associated with therapy-related MDS, but not associated with adverse prognosis independent of TP53. Common in CHIP and CCUS.
UBA1	<u>Missense</u> : exon 3 M41T, M41V, M41L, and others ^f	~5%	VEXAS syndrome ^f (Vacuoles, E1 enzyme, X-linked, Autoinflammatory, Somatic) associated with systemic autoinflammatory and hematologic diseases, mainly MDS.

^a The specific mutations listed in this table are likely to be somatic if found in tumor material. Their absence in non-hematopoietic tissues would be required to prove that they are acquired. Known gene polymorphisms frequent in the population should be excluded from DNA sequencing results as they are likely germline variants and not evidence of clonal hematopoiesis.

^b There are microdeletions that would be missed by typical genetic sequencing or karyotype that affects some of the same genes that may be indicative of clonal hematopoiesis.

^c Somatic mutations in several MDS-associated genes (eg, *TET2*, *DNMT3A*, *TP53*) can occur in non-disease states and no gene mutation is diagnostic of MDS. Mutations in several genes can occur in neoplasms other than MDS, including lymphoid malignancies such as CLL and ALL. Mutations should not be used as presumptive evidence of MDS when diagnostic criteria for MDS have not been met.

^d Constitutional (germline) mutations in these genes can occur and cause a hematopoietic phenotype. Mutations identified in testing blood or marrow for somatic mutations associated with MDS can identify constitutional (germline) mutations. Distinguishing constitutional from somatic mutations often requires sequencing DNA from a non-hematopoietic tissue in MDS.

^e Mutation type definitions: Nonsense – a mutation that changes an amino acid codon into a premature stop codon. Frameshift – the insertion or deletion of DNA base pairs that changes the amino acid reading frame. Missense – a mutation that changes one amino acid codon into another (eg, K700E indicates that the lysine [K] at codon 700 was mutated to a glutamic acid [E]). If no new amino acid is specified for a codon in the table, then it may be mutated into one of several possible amino acids (eg, R882 indicates that the arginine [R] at position 882 can be mutated in more than one way). Splice Site – a mutation that alters the first or second bases immediately before or after an exon.

^f Consider consulting a rheumatologist. JAK2 inhibitors and/or HMAs may potentially be used for these patients.

Note: All recommendations are category 2A unless otherwise indicated.

Continued
MDS-C
2 OF 4



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENES FREQUENTLY SOMATICALLY MUTATED IN MDS REFERENCES

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Note: All recommendations are category 2A unless otherwise indicated.



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Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENETIC FAMILIAL HIGH-RISK ASSESSMENT: HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

Evaluation for Suspected Hereditary Myeloid Malignancy Predisposition Syndromes (HMMPS)

WHOM TO TEST?

- Allogeneic related donor HCT candidate of patients with suspected HMMPS
- Clinically suspected genetic predisposition syndrome at any age^a
- All patients <50 y with MDS or AML^b
- "Hypocellular MDS"^{c,1}
- Newly diagnosed aplastic anemia
- Personal history of MDS or AML (including therapy-related) and ≥1 additional cancer(s)²

Potential pathogenic germline variant found on "somatic" mutation panels

^a Suggestive features:

- Personal history of congenital anomalies and/or other manifestations concerning for an HMMPS, including so-called inborn errors of immunity (eg, early-onset and/or multiple cancers, excessive toxicity with chemotherapy or radiation, hypocellular marrow, poor stem cell mobilizer, unexplained cytopenias or macrocytosis, pulmonary and/or liver fibrosis, immune deficiency/dysregulation ± laboratory findings of humoral and/or cellular immunodeficiency).
- Relative with one or more of the following: acute leukemia or MDS or other manifestations (see above bullet) concerning for an HMMPS.
- Member of a family with a genetically defined HMMPS.

^b The precise age cut-off for risk of inherited predisposition is not known. Note DDX41 may present above this age. Some syndromes are particularly enriched among children and young adults with chromosome 7 abnormalities. See [Genetic/Familial High-Risk Assessment: Breast, Ovarian, Pancreatic, and Prostate](#)

Note: All recommendations are category 2A unless otherwise indicated.

INITIAL TESTING

- Peripheral blood testing
 - FCM for PNH
 - Telomere length by flow FISH
 - Chromosomal breakage study^d
 - Consider syndrome-specific testing based on clinical suspicion^e
- Skin biopsy for fibroblast culture^f (for DNA for germline genetic testing)
 - Consider upfront to avoid unnecessary delay
 - In select settings
- Additional bone marrow testing
 - CGAT/CMA

SUBSEQUENT STEPS

- The presence of a PNH clone^{3,4} or 6p^{4,5,6} loss of heterozygosity (LOH) are associated with acquired diseases. These findings have not been rigorously established to exclude a germline disorder.
- If abnormally short telomere length and clinically suspected short telomere syndrome, consider panel-based multigene sequencing of germline DNA (eg, fibroblast DNA or remission sample)^g (Note: telomere length in patients with short telomere syndromes presenting as adults may not be markedly short)
- If chromosomal breakage studies are positive, consider panel-based multigene sequencing or whole exome or genome sequencing of germline DNA^g
- If initial testing is negative, consider panel-based sequencing of germline DNA or whole exome or genome sequencing of germline DNA^g

- Potential pathogenic germline variant found on "somatic" mutation panels
- If somatic NGS panel is suggestive of germline mutation, send confirmatory sequencing or whole exome or genome sequencing of germline DNA. Peripheral blood telomere length and chromosomal breakage studies may also be relevant^g

^c "Hypocellular MDS" is currently not a distinct entity recognized by the WHO and presents a diagnostic challenge. Bennett JM, et al. Haematologica 2009;94:264-268.

^d If testing returns negative and clinical suspicion of Fanconi anemia (FA) persists, repeat on cultured skin fibroblasts to exclude somatic reversion.

^e Serum pancreatic isoamylase (pediatric and adult patients) and serum isoamylase (pediatric patients) for Shwachman-Diamond syndrome and erythrocyte adenosine deaminase for Diamond-Blackfan anemia.

^f Skin fibroblast culture and DNA isolation are available at select centers and commercially.

^g Genetic counseling is needed prior to testing and consultation with an HMMPS expert may be helpful.

[References on MDS-D 6 of 6](#)

[Continued](#)

MDS-D
1 OF 6



GENETIC FAMILIAL HIGH-RISK ASSESSMENT: HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

- Recognition of these predisposition syndromes is clinically relevant for active therapeutic decisions, familial screening, and further investigations.
 - ▶ Patients may require surveillance for disease-specific serious extra-hematopoietic complications and malignant clonal hematopoiesis evaluation.
 - ▶ In the setting of HCT consideration, specialized evaluations of a familial donor are warranted as well as potential use of a modified conditioning regimen.
 - ▶ The recognition of a familial genetic disorder also allows for appropriate genetic counseling and follow-up of affected family members.^{7,8}
- Increased treatment-related toxicity and prolonged post-treatment aplasia have been observed in patients with MDS/AML with these hereditary syndromes. Early referral to a transplant center and early HCT donor identification should be considered.
- Constitutional mutations predisposing to myeloid malignancy can occur without clinical stigmata of an inherited disorder or family history due to phenotypic heterogeneity, which reflects overlapping features between inherited syndromes and also variable expressivity within a syndrome. Also, a concerning family history of an inherited disorder is not expected in patients in whom the disease-causing mutation occurred de novo. Additionally, as there can be genetic anticipation in the short telomere syndromes, a child may be clinically affected, and the genetically affected parent clinically unaffected or less severely affected.
- Patients harboring these constitutional mutations can present to both pediatric and adult care centers. For example, patients who are older harbor germline predisposition mutations may demonstrate longer latency for disease development, as seen with germline *DDX41* mutations.⁹ Patients <50 y with MDS and those with therapy-related myeloid malignancies may be more likely to harbor germline variants in these cancer predisposition genes.^{10,11,12}

[References on MDS-D 6 of 6](#)

[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.

MDS-D
2 OF 6



GENETIC FAMILIAL HIGH-RISK ASSESSMENT: HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

Below is tailored to heritable hematologic malignancy predisposition syndromes; for a broad and more detailed discussion of cancer risk assessment and counseling, see the [NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, Pancreatic, and Prostate](#).

- Principles of Cancer Risk Assessment and Counseling. Consultation with a heritable hematologic malignancy predisposition syndrome expert may be helpful at all stages below:

1. Pre-test counseling prior to ordering testing
2. Appropriate DNA source for germline genetic testing
3. Consideration of the appropriate genetic testing methodologies and other diagnostic testing
4. Testing results disclosure and post-test counseling
5. Limitations of the proposed approach
6. Surveillance

1. Pre-test counseling includes the following elements:

- Evaluation of patient's needs and concerns regarding:

- Knowledge of genetic testing for cancer and/or other inherited bone marrow failure risks, including risks, benefits, and limitations of testing and the implications of test results for family members
 - ◊ Specific issues to discuss:
 - Mutations identified in blood or marrow for somatic mutations associated with MDS can identify constitutional (germline) mutations providing rationale to test a constitutional tissue.
 - Distinguishing constitutional versus somatic mutations may require sequencing DNA from a non-hematopoietic tissue in blood-based cancers.

- Goals for cancer family risk assessment

- Detailed family history (including cancers and age at diagnosis and multiple cancers in a single individual, cytopenias, immune deficiency/dysregulation, congenital malformations, short stature, developmental delays, pulmonary or liver fibrosis, and ancestry with notation if any consanguinity)

- Detailed past medical history and review of systems, including:

- Documentation of prior genetic testing results of patient and family members
- Personal cancer history (age of diagnosis, treatment-related toxicities, and attention to solid and liquid malignancies in the same individual)
- Personal history of cytopenias, immune deficiency/dysregulation, congenital malformations, short stature, developmental delays, and pulmonary or liver fibrosis
- Reproductive history

- Complete physical examination

- Generation of a differential diagnosis and educating the patient on inheritance pattern, penetrance, variable expressivity, and the possibility of genetic heterogeneity

- Discussion of possible genetic testing result outcomes, including positive (pathogenic or likely pathogenic), negative, variants of undetermined significance, and mosaic results

- Obtaining written informed consent from patient for testing

- Discussion of the clinical implications of testing results to the patient

- Discussion of the clinical implications of testing results to potentially affected family members and their available options for risk assessment, testing, and management

- Cost of genetic testing

- Current legislation regarding genetic discrimination and the privacy of genetic information

[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.

MDS-D
3 OF 6

**GENETIC FAMILIAL HIGH-RISK ASSESSMENT: HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES****2. Appropriate DNA source for germline genetic testing**

- When clinically possible, cultured skin fibroblasts are the recommended DNA source for germline testing in order to exclude somatic mutations and to avoid false negatives due to peripheral blood/marrow somatic mosaicism or somatic genetic reversion events.^{13,14,15}
 - ▶ Utilizing skin fibroblasts upfront (as opposed to initial testing of DNA from blood or marrow) may avoid unnecessary treatment delay, effort, cost, and anxiety surrounding counseling patients regarding possible inherited variants detected on tumor-only testing that subsequently proves to be acquired.
 - ▶ Buccal samples can be considered, acknowledging the risk of peripheral blood contamination.
 - ▶ Peripheral blood during disease remission may be considered with the limitation that acquisition of a dominant revertant clone can occur in individuals with germline mutations. In this setting, genetic testing of blood/marrow-derived DNA could miss the germline mutation (eg, germline mutations in *SAMD9L*¹⁶ or *SAMD9L*).^{14,16,17}
- ▶ See [NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric](#) for information about constitutional mismatch repair deficiency.
- ▶ See [NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, Pancreatic and Prostate](#) for information about Li-Fraumeni syndrome.

3. Consideration of the appropriate genetic testing methodologies and other diagnostic testing

- Multigene testing (aka NGS-based panel testing)
- Accurate interpretation of germline (or somatic) mutation testing is essential for effective medical care.
- As commercially available tests differ in the specific genes analyzed, variant classification, and other factors, it is important to consider the indication for testing and the expertise of the laboratory when choosing the specific laboratory and test panel.
 - ▶ The interpretation of genetic testing remains subjective and complex. Interpretations may differ by laboratory. Mutations may be reclassified as additional data emerge in the field (ie, mutations initially deemed pathogenic may be reconsidered and reclassified as nonpathogenic or vice versa).
- Mutations identified in testing blood or marrow for somatic mutations associated with MDS can identify constitutional (germline) mutations, but somatic panels are often not comprehensive and so a negative somatic panel does not rule out a constitutional mutation.^{18,19}
- Genetic testing performed to identify somatic mutations arising in malignant cells is often not designed to detect germline (that is, inherited) mutations and may thus be inadequate for evaluation of an underlying heritable hematologic malignancy predisposition syndrome. Specifically, somatic mutation panels may not target the relevant genomic locus and/or detect relevant copy number aberrations implicated in inherited disorders.¹⁸
- NGS and chromosome genomic array testing (CGAT) are complementary in detecting both mutations and copy number aberrations and copy-neutral LOH (cnLOH) in genes associated with these disorders.
- Additional laboratory testing can assist in diagnosing these disorders.
 - ▶ Fanconi anemia (FA) is evaluated by chromosome breakage analysis.
 - ▶ Serum pancreatic isoamylase (pediatric and adult patients) and serum trypsinogen (pediatric patients) are often low in Shwachman-Diamond syndrome.
 - ▶ Short telomere syndromes, such as dyskeratosis congenita, demonstrate shortened telomere lengths, which can be measured by fluorescence in situ hybridization (FISH) assays using leukocyte subsets, although in patients who are older telomere length results may not be sensitive or specific and may require complementary genetic evaluation to aid in interpretation.^{20,21}
 - ▶ Erythrocyte adenosine deaminase is often elevated in Diamond-Blackfan anemia.²²

[References on MDS-D 6 of 6](#)
[Continued](#)

Note: All recommendations are category 2A unless otherwise indicated.

MDS-D
4 OF 6



GENETIC FAMILIAL HIGH-RISK ASSESSMENT: HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

4. Post-test counseling done when the test results are disclosed

- Discuss results and associated medical risks.
- Interpret results in context of patient's presentation.
- Discuss recommended medical management.
- Discuss and help to facilitate education and testing of family members at risk for heritable malignancy predisposition syndrome.
- Discuss available resources such as high-risk clinics, disease-specific support groups, and research studies.
- For patients of reproductive age, advise about options for prenatal diagnosis and assisted reproduction, including pre-implantation genetic testing.
- Consider carrier status implications of autosomal recessive disorders.

5. Limitations of the proposed approach

- The current criteria are focused on known genetic predisposition syndromes for MDS or AML. The proposed age threshold of 50 y at diagnosis is arbitrary and may miss some patients with underlying heritable risk. A notable example of this is *DDX41*. Germline *DDX41* variants have been reported in ~2% to 6% of unselected adult patients with myeloid malignancy,^{23,24,25} which makes *DDX41* one of the most common predisposition genes for myeloid malignancy in adult patients. These patients are commonly diagnosed with their AML/MDS after 50 y. Additionally, likely not all genetic predisposition syndromes have been defined and so the current criteria for testing may change over time. Any clinical suspicion of hereditary predisposition warrants a referral to an institution with expertise in the field.
- Initial testing: Telomere length measurement by flow-FISH to assess the risk of telomere-mediated disease in patients with hematologic malignancies where there are circulating malignant cells may be confounded or falsely shortened secondarily due to the malignancy itself. In such cases, germline genetic assessment should be performed in lieu of telomere length measurement and telomere length measurement should be assessed during remission where possible. In some cases of familial disease, assessment of telomere length in a relative with an identical variant in a telomere gene could also be used for interpreting the significance of the variant (optional). Additionally, if there are circulating malignant cells or the malignant cell composition in peripheral blood is unknown, the finding of abnormally short telomere length measurement alone should be interpreted with caution and additional evidence of a telomere-mediated process is needed including the presence of a germline variant of clinical features including a family history of pulmonary fibrosis.
- In the absence of a genetically confirmed heritable hematologic malignancy predisposition syndrome, a concerning personal/or family history may warrant consideration of an unrelated over a related donor for allogeneic HCT.

6. Surveillance

- Individuals who fulfill the clinical diagnostic criteria for a myeloid neoplasm with a germline predisposition should undergo surveillance, even if the pathogenic genetic variant is undetermined.
- Individuals with a deleterious or likely deleterious genetic variant associated with a germline predisposition should undergo surveillance, regardless of clinical presentation.

7. Management considerations

- The presence of a syndrome with noted high penetrance of myeloid malignancy or high-risk findings (such as somatic 2nd hit of *RUNX1*, *DDX41*, *CEBPA*, or biallelic *TP53* loss) warrants timely referral to an academic center for assessment by a team with expertise in HMMPS and HCT evaluation for appropriate timing.

Note: All recommendations are category 2A unless otherwise indicated.

[References on MDS-D 6 of 6](#)

MDS-D
5 OF 6



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENETIC FAMILIAL HIGH-RISK ASSESSMENT: HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

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Note: All recommendations are category 2A unless otherwise indicated.

MDS-D
6 OF 6



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

[NCCN Guidelines Index](#)[Table of Contents](#)[Discussion](#)

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Germline predisposition for myeloid neoplasms <i>without</i> cytopenia(s), dysplasia, or other organ dysfunction prior to myeloid malignancy presentation				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
CEBPA ¹	CEBPA	AML	~90% for germline N-terminal (frameshift) mutations ^{1,2,3} and ~50% for germline C-terminal bZIP region mutations ^{b,4,5}	AML (not associated with MDS development) is typically favorable risk and characterized by acquisition of a second somatic mutation in <i>CEBPA</i> . The germline mutation most commonly affects the N-terminus whereas the somatic mutation arises in the C-terminus bZIP region (predominantly missense or in-frame indels) with different somatic mutations occurring with AML recurrence. ² ~5% to 10% of <i>CEBPA</i> double-mutant AML cases harbor germline mutations. ⁶ Less commonly, familial AML due to germline mutations in the C-terminus bZIP region have also been reported. ^{4,5}
DDX41-associated predisposition to myeloid malignancy ⁷	DDX41	AML, MDS, CML	<ul style="list-style-type: none"> Estimates vary. Penetrance is higher in males than females ~50% (estimated by an analysis of 1st degree relatives of patients with germline <i>DDX41</i> mutations with MDS/AML)⁸ ~3% (estimated by a UK Biobank population-based analysis)⁹ 	Patients often have macrocytosis and/or cytopenias prior to myeloid malignancy development. ¹⁰ Median age of onset of myeloid malignancy is ~ 66 y, like sporadic AML/MDS. ¹¹⁻¹⁴ Risk of myeloid malignancy is negligible prior to ~ 40 y. ⁸ Myeloid malignancy development is associated with biallelic <i>DDX41</i> mutations due to acquisition of a somatic mutation in the wild-type allele in ~55% to 70% of AML/MDS cases. Most commonly, the somatic mutation is R525H. ^{8,12,13} AML is commonly characterized by hypocellularity, low blast percentage, and a normal karyotype. ^{14,15}
14q32.2 genomic duplication ¹⁶	Includes <i>ATG2B</i> and <i>GSKIP</i>	AML, MPN, CMML (highly penetrant)	Not established	Familial MPN. Earlier age of onset compared to sporadic MPN.

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

^b Notably, numbers are limited.

Note: All recommendations are category 2A unless otherwise indicated.

[Continued](#)

MDS-E
1 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Germline predisposition for myeloid neoplasms <u>with</u> pre-existing cytopenia(s) and/or other organ dysfunction prior to myeloid malignancy presentation				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
ANKRD26 ¹⁷	ANKRD26	Moderate thrombocytopenia with mild bleeding manifestations; platelet size is usually not enlarged; dysmegakaryopoiesis ¹⁸ /AML, MDS	7.1%; CML incidence of 1.3% ¹⁹	Non-syndromic autosomal dominant thrombocytopenic disorder characterized by normal platelet size, moderate thrombocytopenia, and absent or mild bleeding tendency. ²⁰
ETV6 ^{21,22}	ETV6	Thrombocytopenia and mild bleeding manifestations; platelet size is usually not enlarged ²³ /AML, MDS	Not established	ALL (typically precursor B-cell ALL) is more prevalent than myeloid malignancy. The ratio of lymphoid versus myeloid malignancies is approximately 2:1. ^{21,23}
MECOM-associated syndrome	MECOM (<i>MDS1</i> and <i>EVI1</i> complex locus) on 3q26.2	Amegakaryocytic thrombocytopenia; B-cell deficiency; hypocellular marrow failure/ MDS ^{24,25}	Not established	Skeletal abnormalities including radioulnar synostosis, clinodactyly, cardiac and renal malformations, B-cell deficiency, and presenile hearing loss ^{25,26} Also known as EVI1; MDS1; KMT8E; PRDM3; RUSAT2; MDS1-EVI1; AML1-EVI-1
GATA2 deficiency syndrome ^{27,28}	GATA2	Bone marrow failure; moncytopenia/AML, MDS; B-/NK-/CD4-cell lymphocytopenia; highly penetrant ²⁹	Not established ^{30,31}	Immune deficiency (ie, viral infections, warts, disseminated nontuberculous mycobacterial infections), wide range of extra-hematopoietic manifestations (eg, lymphedema, sensorineural hearing loss, pulmonary alveolar proteinosis) ³² ; megakaryocyte atypia; pediatric MDS w/-7/del(7q), trisomy 8, or der(1;7). ³³ Somatic reversion events are possible. ³¹

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

Note: All recommendations are category 2A unless otherwise indicated.

Continued
MDS-E
2 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Germline predisposition for myeloid neoplasms <i>with</i> pre-existing cytopenia(s) and/or other organ dysfunction prior to myeloid malignancy presentation				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
Familial platelet disorder with associated myeloid malignancy ^{b,34,35}	<i>RUNX1</i>	Thrombocytopenia and abnormal platelet function/AML, MDS; highly penetrant ^c	35%-40% ³⁶	Typical age of onset of AML/MDS is 20–40 y. Anticipation may lead to occurrence in younger individuals in subsequent generations; eczema; ALL also seen.
LIG-4 syndrome ³⁷	<i>LIG4</i>	Marrow failure, lymphoid malignancy	Not established	Short stature, microcephaly, combined immunodeficiency.
Xeroderma pigmentosum C (XPC) ^{38,39}	<i>XPC</i> ^{delTG}	Increased myeloid malignancies and T-cell ALL in people aged 7–29 y.	Not established	Sensitivity to ultraviolet light, experiencing severe sunburns within minutes of exposure, dry skin (xeroderma), freckling (pigmentosum), hearing loss, poor coordination, loss of intellectual function, seizures, and development of squamous cell carcinomas and melanomas often as early as 10 y in sun-exposed areas.
ERCC6L2 ⁴⁰⁻⁴²	<i>ERCC6L2</i>	Marrow failure/AML, MDS	Not established	Skeletal/cardiac abnormalities, neurological defects also associated with somatic <i>TP53</i> mutations and erythroleukemia. Pre-existing cytopenias, microcephaly, developmental delay, and other congenital abnormalities.

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

^b Notably, numbers are limited.

^c Additional laboratory testing: *RUNX1* mutant platelets may show platelet ultrastructure changes such as abnormal alpha granules and a deficiency of delta granules. Platelet aggregometry and platelet function analyzer testing may show platelet aggregation and secretion defects, such as decreased aggregation to epinephrine and collagen (so called aspirin-like defect).

Note: All recommendations are category 2A unless otherwise indicated.

Continued
MDS-E
3 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Germline predisposition for myeloid neoplasms <u>with</u> pre-existing cytopenia(s) and/or other organ dysfunction prior to myeloid malignancy presentation				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
SAMD9/SAMD9L syndromes ^{31,43-45}	SAMD9 SAMD9L	Transient or permanent cytopenias and hypocellular marrow failure/AML, MDS	Not established	MIRAGE (SAMD9): MDS, infection, restriction of growth, adrenal hypoplasia, genital phenotypes, and enteropathy; MDS with monosomy 7/-7q, somatic genetic aberrations in hematopoietic cells often occur that result in loss of the mutant SAMD9 allele. ⁴³ Ataxia-pancytopenia syndrome (SAMD9L): cerebellar atrophy and white matter hyperintensities, gait disturbance, nystagmus, immune deficiency; MDS with monosomy 7/-7q; somatic genetic aberrations in hematopoietic cells often occur that result in loss of the mutant SAMD9L allele. ⁴⁴ Can have overlap in phenotype between SAMD9 and SAMD9L disorders.
SRP72 ⁴⁶	SRP72	Marrow failure/MDS	Not established	Congenital sensorineural deafness.

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

Note: All recommendations are category 2A unless otherwise indicated.

Continued
MDS-E
4 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Classical inherited bone marrow failure syndromes				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
Diamond-Blackfan anemia ^d	<i>RPL5, RPL11, RPL15, RPL23, RPL26, RPL27, RPL31, RPL35A, RPS7, RPS10, RPS17, RPS19, RPS24, RPS26, RPS27, RPS28, RPS29, TSR2, GATA1</i>	Anemia and marrow erythroid hypoplasia/AML, MDS	~5% risk by 45–50 y ^{47,48}	Cardiac anomalies, Cathie facies, genitourinary anomalies, cleft lip/palate, short stature; sarcomas; elevated erythrocyte adenosine deaminase.
Fanconi anemia ^{e,f}	<i>FANCA, FANCB, FANCC, FANCD1/BRCA2, FANCD2, FANCE, FANCF, FANCG, FANCI, FANCJ/BRIP1/BACH1, FANCL, FANCM, FANCN/PALB2, FANCO/RAD51C, FANCP/SLX4, FANQ/ERCC4, FANCR/RAD51, FANCS/BRCA1, FANCT/UBE2T, FANCU/XRCC2, FANCV/REV7/MAD2L2</i>	Bone marrow failure/AML, MDS	10% AML 90% bone marrow failure ⁴⁹	Short stature, skin pigmentation (café-au-lait or hypopigmented spots), skeletal anomalies (thumbs, arms), multiple other congenital anomalies; squamous cell carcinomas of head/neck/vulva/vagina, liver tumors, additional solid tumors associated with <i>FANCD1</i> include brain and Wilms tumors; therapy-related neoplasms may emerge after treatment for solid tumors; increased chromosome fragility. Cumulative incidence of solid cancers is extremely high in patients with bi-allelic <i>FANCD1/BRCA2</i> mutations (97% at the age of 7 y).
Shwachman-Diamond syndrome ^g	<i>SBDS, EFL1, DNAJC21</i>	Bone marrow failure/AML, MDS	Not established ⁵⁰	Pancreatic insufficiency, skeletal abnormalities; low serum trypsinogen or pancreatic isoamylase; somatic mutations in <i>EIF6 & TP53</i> . ⁵¹

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

^d Additional laboratory testing: Erythrocyte adenosine deaminase is often elevated.

^e Some FA genes overlap with inherited breast and ovarian cancer genes.

^f Additional laboratory testing: Increased chromosomal breakage following exposure to a DNA cross-linking agent such as mitomycin C or diepoxybutane. Testing is typically performed on peripheral blood lymphocytes. A subset of patients may undergo genetic somatic reversion to wild-type in peripheral blood lymphocytes. This reversion confers a growth advantage over the non-reverted FA lymphocytes. In such cases, testing may appear normal, or reveal only a small subpopulation of cells with increased chromosomal breakage. If there is a strong clinical suspicion for FA despite a negative blood test, chromosomal breakage may be tested on fibroblasts obtained from a skin biopsy.

^g Additional laboratory testing: Serum pancreatic isoamylase (pediatric and adult patients) and serum trypsinogen (pediatric patients) are often low.

Note: All recommendations are category 2A unless otherwise indicated.

Continued
MDS-E
5 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Classical inherited bone marrow failure syndromes				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
Short telomere syndromes ^h	<i>ACD, CTC1, DKC1, NAF1, NHP2, NOP10, PARN, POT1, RTEL1, TERC, TERT, TINF2, WRAP53, ZCCHC8</i> ⁵²	Bone marrow failure/AML, MDS	10% with the highest risk above the age of 50 y ⁵³⁻⁵⁵	Idiopathic pulmonary fibrosis, emphysema, early hair graying, osteoporosis, pulmonary arteriovenous malformations and hepatopulmonary syndrome, liver fibrosis-cirrhosis, esophageal stricture, enterocolitis, immune deficiency; rare cases manifest as dyskeratosis congenita with nail dystrophy, rash, oral leukoplakia; squamous cell carcinomas of head/neck/GI tract; shortened telomere lengths. Somatic reversion events are possible. 10% lifetime risk has a competing risk of mortality due to pulmonary fibrosis.
Congenital neutropenia	<i>ELANE, G6PC3, GF11, HAX1</i>	Neutropenia/AML, MDS	Not established	<i>G6PC3</i> mutations can be associated with congenital anomalies. ⁵⁶ <i>HAX1</i> mutations can be associated with neurologic manifestations including seizures. ⁵⁷
Myeloid neoplasms associated with Down syndrome	<i>Trisomy 21, GATA1</i>	Transient abnormal myelopoiesis/AML, MDS	Not established	Down syndrome; acute megakaryoblastic leukemia.

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

^h Additional laboratory testing: Shortened telomere lengths measured by FISH assays on peripheral blood leukocyte subsets.

Note: All recommendations are category 2A unless otherwise indicated.

Continued
MDS-E
6 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES^a

Germline predispositions for myeloid neoplasms and solid tumor cancers				
Disorder	Gene	Hematologic Findings/ Myeloid Malignancy	Lifetime Risk of MDS/AML	Other Phenotypes and Clinical Features
Constitutional mismatch repair deficiency	<i>EPCAM, MLH1, MSH2, MSH6, PMS2</i>	AML, MDS	Not established	Café-au-lait spots; ALL, lymphomas, central nervous system, GI, and other tumors; microsatellite instability of tumor cells.
Hereditary breast and ovarian cancer ^e	<i>BRCA1, BRCA2</i>	AML, MDS	Not established	Breast and ovarian cancers, other tumors. Therapy-related neoplasms may emerge after treatment for solid tumors.
Li-Fraumeni syndrome	<i>TP53</i>	AML, MDS	70% for all cancers in males 90% for all cancers in females	AML and MDS are associated with complex karyotypes as seen with somatic <i>TP53</i> mutations; ALL, adrenocortical carcinoma, brain cancer, breast cancer, choroid plexus carcinoma, colon cancer, lung carcinoma, sarcoma, other tumors; therapy-related neoplasms may emerge after treatment for solid tumors.
RASopathies	<i>CBL, KRAS, NF1, PTPN11</i>	AML, MDS	Not established	Mutations induce constitutive activation of RAS/MAPK pathways and cause many syndromic findings and hematologic and solid tumor cancer risk (neuro-cardio-fascio cutaneous syndrome), eg, neurofibromatosis type 1 and Noonan syndrome, which predispose to development of JMML or an MPN.
Other rare DNA repair syndromes	<i>BLM, MBD4, XPC</i> ³⁷	AML, <i>MBD4</i> : early-onset AML with a high somatic mutation burden characterized by CG>TG changes including biallelic CG>TG mutations in <i>DNMT3A</i> ⁵⁸	Not established	Bloom syndrome: pre- and postnatal growth retardation, photosensitive skin changes, immunodeficiency, insulin resistance, microcephaly, high-pitched voice, hypogonadism, and increased risk of early onset of multiple cancers.

[References on MDS-E 8 of 10](#)

^a The list of genes associated with heritable hematologic malignancy predisposition syndromes is continually evolving. Not all of the listed individual genes under the Gene column have been reported in myeloid malignancies.

^e Some FA genes overlap with inherited breast and ovarian cancer genes.

Note: All recommendations are category 2A unless otherwise indicated.

MDS-E
7 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

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Continued

Note: All recommendations are category 2A unless otherwise indicated.

MDS-E
8 OF 10



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES

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Note: All recommendations are category 2A unless otherwise indicated.

Continued

MDS-E
9 OF 10



GENE MUTATIONS ASSOCIATED WITH HEREDITARY MYELOID MALIGNANCY PREDISPOSITION SYNDROMES
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Note: All recommendations are category 2A unless otherwise indicated.

MDS-E
10 OF 10

**RECOMMENDATIONS FOR FLOW CYTOMETRY****Initial Evaluation (MDS-1)**• **FCM:**

- ▶ Consideration should be given to obtain FCM testing at initial evaluation of MDS to include antibody combinations to characterize blasts and to identify abnormal lymphoid populations (such as increased hematogones, which may mimic blasts, leading to erroneous myeloblast quantitation). For example, a combination using anti-CD45, -CD34, -CD33, and -CD19 (with forward scatter and side scatter) could be useful.
- ▶ It is understood that the blast percent for both diagnosis and risk stratification should be determined by morphologic assessment, not solely by FCM. If blasts are increased and morphologic questions arise regarding their subtype (ie, myeloid or lymphoid), they should be characterized with a more elaborate panel of antibodies.
- ▶ In diagnostically difficult cases, in expert hands, an expanded panel of antibodies to demonstrate abnormal differentiation patterns or aberrant antigen expression may help confirm diagnosis of MDS (see *Initial Evaluation* in the [Discussion](#)).
- ▶ Flow cytometric abnormalities are often seen in MDS, and in some cases may correlate with observed morphologic abnormalities. They may also help diagnostically in patients with clinical suspicion of MDS who have no significant morphologic dysplasia and whose chromosome/FISH studies are either negative or normal.
- ▶ FCM is most useful in detecting aberrant immature myeloid lineages often observed in MDS.¹⁻⁶ Flow analysis will detect aberrant expression of B- or T-cell antigens on myeloid precursors, and selective loss or gain of additional markers (eg, loss or dim expression of CD33, CD34, CD56, CD38, or CD117) on myeloid precursors. Flow will help in cytopenia associated with LGL expansion by detecting increase of CD56/CD57+ cells. CMML-associated monocytic aberrancies can be easily detected by a combination of CD64/CD14, and CD16 loss or dim⁶ expression. In addition, qualitative abnormalities in mature myeloid lineages, eg, hypogranular late myelocytes, bands/Pelger-Huet cells, and neutrophils will have abnormal flow patterns (low or negative for CD16 or CD10). However, the erythroid lineage dysplasia (dyserythropoiesis) detection by FCM is limited^{4,7} due to variable RBC lysing methods used in preparing flow mononuclear cell suspension. Megakaryocytic dysplasia cannot be assessed in FCM.

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Note: All recommendations are category 2A unless otherwise indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

ABBREVIATIONS						
aCML	atypical chronic myeloid leukemia	FA	Fanconi anemia	JMML	juvenile myelomonocytic leukemia	
ALL	acute lymphoblastic leukemia	FAB	French American British			
AMC	absolute monocyte count	FCM	flow cytometry	L	low	
AML	acute myeloid leukemia	FISH	fluorescence in situ hybridization	LB	low blasts	
AML-t	AML transformation			LDH	lactate dehydrogenase	
APL	acute promyelocytic leukemia	G-CSF	granulocyte colony-stimulating factor	LFS	leukemia-free survival	
ASTCT	American Society for Transplantation and Cellular Therapy	GI	gastrointestinal	LGL	large granular lymphocyte	
ATG	antithymocyte globulin	H	high	LOH	loss of heterozygosity	
BPDCN	blastic plasmacytoid dendritic cell neoplasm	H&P	history and physical			
		HCT	hematopoietic cell transplant	MD	myelodysplastic	
		HIV	human immunodeficiency virus	MDS	myelodysplastic syndromes(s)	
CBC	complete blood count	HLA	human leukocyte antigen	MH	moderate high	
CCUS	clonal cytopenia of undetermined significance	HMA	hypomethylating agent	mIDH1	mutant IDH1	
CGAT	chromosome genomic array testing	HMMPS	hereditary myeloid malignancy predisposition syndromes	ML	moderate low	
CHIP	clonal hematopoiesis of indeterminate potential	IB	increased blasts	MLD	multilineage dysplasia	
CHRS	clonal hematopoiesis risk score	ICC	International Consensus Classification	MP	myeloproliferative	
CMA	chromosome microarray analysis	ICUS	idiopathic cytopenia of unknown significance	MPN	myeloproliferative neoplasm(s)	
CML	chronic myeloid leukemia	IPSS	International Prognostic Scoring System	NGS	next-generation sequencing	
CMMI	chronic myelomonocytic leukemia	IPSS-M	International Prognostic Scoring System Molecular	NOS	not otherwise specified	
CMV	cytomegalovirus	IPSS-R	Revised International Prognostic Scoring System	OS	overall survival	
cnLOH	copy-neutral loss of heterozygosity	IST	immunosuppressive therapy	PCR	polymerase chain reaction	
CNV	copy number variant	IWG	International Working Group	PNH	paroxysmal nocturnal hemoglobinuria	
CSA	congenital sideroblastic anemia					
EB	excess blasts					
ESA	erythropoiesis-stimulating agent					

[Continued](#)



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

ABBREVIATIONS

RAEB	refractory anemia with excess blasts	VAF	variant allele frequency
RARS	refractory anemia with ring sideroblasts	VH	very high
RCMD	refractory cytopenia with multilineage dysplasia	VL	very low
RCUD	refractory cytopenia with unilineage dysplasia	WBC	white blood cell
RBC	red blood cell	WPSS	World Health Organization-Based Prognostic Scoring System
RS	ring sideroblasts	XPC	xeroderma pigmentosum C
RS-T	ring sideroblasts and thrombocytosis		
SLD	single lineage dysplasia		
SM-AHN	systemic mastocytosis with associated hematologic neoplasm		
T	thrombocytosis		
TIBC	total iron-binding capacity		
T-LGL	T-cell large granular lymphocyte		
TSH	thyroid-stimulating hormone		
U	unclassified		



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

NCCN Categories of Evidence and Consensus	
Category 1	Based upon high-level evidence (≥ 1 randomized phase 3 trials or high-quality, robust meta-analyses), there is uniform NCCN consensus ($\geq 85\%$ support of the Panel) that the intervention is appropriate.
Category 2A	Based upon lower-level evidence, there is uniform NCCN consensus ($\geq 85\%$ support of the Panel) that the intervention is appropriate.
Category 2B	Based upon lower-level evidence, there is NCCN consensus ($\geq 50\%$, but $< 85\%$ support of the Panel) that the intervention is appropriate.
Category 3	Based upon any level of evidence, there is major NCCN disagreement that the intervention is appropriate.

All recommendations are category 2A unless otherwise indicated.

NCCN Categories of Preference	
Preferred intervention	Interventions that are based on superior efficacy, safety, and evidence; and, when appropriate, affordability.
Other recommended intervention	Other interventions that may be somewhat less efficacious, more toxic, or based on less mature data; or significantly less affordable for similar outcomes.
Useful in certain circumstances	Other interventions that may be used for selected patient populations (defined with recommendation).

All recommendations are considered appropriate.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Discussion

This discussion corresponds to the NCCN Guidelines for Myelodysplastic Syndromes. Last updated: July 25, 2024

Table of Contents

Overview	MS-2	Supportive Care	MS-21
Guidelines Update Methodology	MS-2	Treatment of Related Anemia	MS-25
Literature Search Criteria	MS-2	Low-Intensity Therapy	MS-29
Sensitive/Inclusive Language Usage	MS-2	High-Intensity Therapy	MS-34
Diagnostic Classification	MS-3	Targeted Therapy	MS-36
Myelodysplastic Syndromes	MS-3		
Myelodysplastic/Myeloproliferative Neoplasms	MS-5		
Indolent Myeloid Hematopoietic Disorders	MS-7		
Childhood MDS	MS-8		
Evaluation	MS-10		
Initial Evaluation	MS-10		
Additional Testing	MS-12		
Evaluation of Related Anemia	MS-14		
Prognostic Stratification	MS-15		
Prognostic Scoring Systems	MS-15		
Molecular Abnormalities in MDS	MS-19		
Comorbidity Indices	MS-20		
Therapeutic Options	MS-20		
		Recommended Treatment Approaches	MS-37
		Therapy for Lower-Risk Disease (IPSS Low, Intermediate-1; IPSS-R Very Low, Low, Intermediate; or WPSS Very Low, Low, Intermediate)	MS-37
		Therapy for Higher-Risk Disease (IPSS Intermediate-2, High; IPSS-R Intermediate, High, Very High; or WPSS High, Very High)	MS-40
		Summary	MS-42
		References	MS-44



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Overview

The myelodysplastic syndromes (MDS) represent myeloid clonal hemopathies with a relatively heterogeneous spectrum of presentation. Diagnosis and disease stratification are based on multiple factors that may include clinical data, morphology of peripheral blood and bone marrow, fluorescence in situ hybridization (FISH), cytogenetics, flow cytometry, and next-generation sequencing myeloid mutation studies. The major clinical problems in these disorders are morbidities caused by cytopenias and the potential for MDS to evolve into acute myeloid leukemia (AML). In addition, there are complications that may arise from chronic transfusions, treatment toxicity, and in some cases, secondary phenomena such as systemic inflammatory conditions.¹ In the general population, the incidence rate of MDS is approximately 4.5 per 100,000 people per year.² MDS is rare among children/adolescents and young adults. Accounting for 1.6% of patients diagnosed with MDS, individuals <40 years of age have an incidence of 0.1 per 100,000 people per year. However, among individuals between ages 70 and 79 years, the incidence rate increases to 26.9 per 100,000 people, and further to 55.4 per 100,000 people among those ≥80 years of age.²

The management of MDS is complicated by the generally advanced age of the patients, median age 77 years,³ the non-hematologic comorbidities commonly seen in this cohort, and the relative inability of older patients to tolerate certain intensive forms of therapy. In addition, when the illness progresses into AML, these patients experience lower response rates to standard therapy than patients with de novo AML.⁴

The multidisciplinary Panel of experts for the NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines[®]) for Myelodysplastic Syndromes meets annually to update recommendations on standard approaches to the diagnosis and treatment of MDS in adults. These recommendations are based on a review of recent clinical evidence that

has led to important advances in treatment or has yielded new information on biologic factors that may have prognostic significance in MDS.

Guidelines Update Methodology

The complete details of the Development and Update of the NCCN Guidelines are available at www.NCCN.org.

Literature Search Criteria

Prior to the update of the NCCN Guidelines[®] for Myelodysplastic Syndromes, an electronic search of the PubMed database was performed to obtain key literature in MDS published since the previous Guidelines update, using the search term: myelodysplastic syndrome. The PubMed database was chosen because it remains the most widely used resource for medical literature and indexes peer-reviewed biomedical literature.⁵

The search results were narrowed by selecting studies in humans published in English. Results were confined to the following article types: Clinical Trial, Phase II; Clinical Trial, Phase III; Clinical Trial, Phase IV; Guideline; Practice Guideline; Meta-Analysis; Randomized Controlled Trial; Systematic Reviews; and Validation Studies. The data from key PubMed articles as well as articles from additional sources deemed as relevant to these guidelines as discussed by the Panel during the Guidelines update have been included in this version of the Discussion section. Recommendations for which high-level evidence is lacking are based on the Panel's review of lower-level evidence and expert opinion.

Sensitive/Inclusive Language Usage

NCCN Guidelines strive to use language that advances the goals of equity, inclusion, and representation.⁶ NCCN Guidelines endeavor to use language that is person-first; not stigmatizing; anti-racist, anti-classist, anti-misogynist, anti-ageist, anti-ableist, and anti-weight biased; and



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

inclusive of individuals of all sexual orientations and gender identities. NCCN Guidelines incorporate non-gendered language, instead focusing on organ-specific recommendations. This language is both more accurate and more inclusive and can help fully address the needs of individuals of all sexual orientations and gender identities. NCCN Guidelines will continue to use the terms men, women, female, and male when citing statistics, recommendations, or data from organizations or sources that do not use inclusive terms. Most studies do not report how sex and gender data are collected and use these terms interchangeably or inconsistently. If sources do not differentiate gender from sex assigned at birth or organs present, the information is presumed to predominantly represent cisgender individuals. NCCN encourages researchers to collect more specific data in future studies and organizations to use more inclusive and accurate language in their future analyses.

Diagnostic Classification

Myelodysplastic Syndromes

The initial evaluation of patients with suspected MDS requires careful assessment of the peripheral blood smear and blood counts, marrow morphology, cytogenetics, duration of abnormal blood counts, other potential causes of cytopenias, and concomitant illnesses. To establish the diagnosis of MDS, careful morphologic review and correlation with the patient's clinical features are important, because a number of medications and viral infections (including human immunodeficiency virus [HIV] infection) can cause morphologic changes in marrow cells that are similar to MDS.^{4,7} The NCCN Guidelines for Myelodysplastic Syndromes include the World Health Organization (WHO) 2016 and 2022 and the International Consensus Classification (ICC) 2022 classification systems for diagnostic evaluations.^{8,9}

To assist in providing consistency in the diagnostic guidelines for MDS, an International Consensus Working Group recommended that minimal diagnostic criteria for this disease include two prerequisites: stable cytopenia (for at least 6 months unless accompanied by a specific karyotype or bilineage dysplasia, in which case only 2 months of stable cytopenias are needed), and the exclusion of other potential disorders as a primary reason for dysplasia or cytopenia or both. In addition, the diagnosis of MDS requires at least one of three MDS-related (decisive) criteria: 1) dysplasia ($\geq 10\%$ in one or more of the three major bone marrow lineages); 2) a blast cell count of 5% to 19%; and 3) a specific MDS-associated karyotype [eg, del(5q), del(20q), +8, or -7/del(7q)]. Furthermore, several co-criteria may help confirm the diagnosis of MDS. These co-criteria include aberrant immunophenotype by flow cytometry, abnormal bone marrow histology and immunohistochemistry, or the presence of molecular markers (ie, abnormal CD34 antigen expression, fibrosis, dysplastic megakaryocytes, atypical localization of immature progenitors, myeloid clonality).¹⁰

Consistent with these recommendations, as stated by WHO, the features that are central for the diagnosis of MDS entail well-defined dysplasia in one or more hematopoietic cell lines in addition to cytopenias. Cytopenias need to be persistent (for at least 4–6 months) and lack other underlying conditions serving as a primary cause of the cytopenia.¹¹ Further, analyses of studies including the MDS databases, which generated the International Prognostic Scoring System (IPSS) and Revised IPSS (IPSS-R), have shown that the use of standard hematologic values to define cytopenic cut points for MDS *diagnosis* are more appropriate than the WHO-recommended *prognostic* cytopenia cut points.¹²

In 2001, WHO proposed an alternative classification for MDS that was modified from the original French-American-British (FAB) definitions.¹³⁻¹⁵ The 2022 WHO classification uses the abbreviation "MDS" for



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

myelodysplastic neoplasms instead of myelodysplastic syndromes.⁸ As such, when referring to the 2022 WHO classification in this discussion, “MDS” refers to myelodysplastic neoplasms. However, the abbreviation “MDS/MPN” refers to myelodysplastic/myeloproliferative neoplasm. The 2022 WHO guidelines identify multiple entities of MDS classified as genetically defined MDS: MDS with low blasts and isolated 5q deletion (MDS-5q; previously MDS-del(5q)), MDS with low blasts and *SF3B1* mutation (MDS-*SF3B1*; previously MDS with ring sideroblasts [MDS-RS]), MDS with biallelic *TP53* inactivation (MDS-*biTP53*); or classified as morphologically defined MDS: MDS with low blasts (MDS-LB; previously MDS with single lineage dysplasia [MDS-SLD] and MDS with multilineage dysplasia [MDS-MLD]), MDS-hypoplastic, MDS with increased blasts 1 (MDS-IB1; previously MDS with excess blasts 1 [MDS-EB1]), MDS with increased blasts 2 (MDS-IB2; previously MDS-EB2), and MDS with fibrosis (see *Pathologic-morphologic classifications of myelodysplastic neoplasms 2023* in the algorithm).⁸ The ICC system identifies the following MDS entities: MDS-del(5q), MDS-*SF3B1*, myeloid neoplasms with *TP53* mutation, MDS not otherwise specified (MDS-NOS), MDS with excess blasts (MDS-EB), and MDS/AML. The Panel cautions that classifications alone do not imply therapeutic choice.

The del(5q) entity is defined by the presence of this deletion and can include one additional cytogenetic abnormality, with the exception of monosomy 7 or del(7q), which is associated with poor outcomes.¹⁶ The modification of this definition stemmed from data that showed a prognostic stratification among patients with del(5q) based on the number of additional cytogenetic abnormalities compared to the single mutation del(5q).¹⁷⁻¹⁹

The division between MDS and AML is a continued area of debate. The original FAB definition of MDS included patients with up to 30% blasts. The 2001 WHO classification reduced the upper limit for blast percentage

for MDS to 19%, rather than the previous cutoff of 29%, thereby reclassifying these patients as “AML with myelodysplasia-related changes.”²⁰ It was noted in the 2008 WHO classification that some patients with AML with myelodysplasia-related changes who have 20% to 29% marrow blasts may behave in a manner more similar to MDS than to AML. Data suggest that these patients have less aggressive disease and improved outcomes and therapeutic responses compared to patients with >30% blasts and should be considered a favorable group of AML.²¹ The NCCN Panel recognizes that MDS are not only related to blast quantitation, but they also possess a differing pace of disease related to distinctive biologic features when compared with de novo AML.^{22,23} Therefore, patients who have 20% to 29% marrow blasts may be considered to have MDS or AML. A 20% blast cut off for AML evolving out of MDS and MDS-EB2 may be arbitrary in some clinical scenarios. AML-style therapies may be considered for appropriate patients with MDS-EB2, especially at younger ages of presentation. Furthermore, a diagnosis of AML may be made with <20% in patients with certain cytogenetic abnormalities (See [NCCN Guidelines for Acute Myeloid Leukemia](#)). Some clinical trials designed for high-grade MDS may allow the enrollment of patients with AML-MDS.^{24,25} Some patients with higher-risk disease with MDS-IB2 could be considered for AML-type therapy.^{8,9} Patients who have previously been included in and benefitted from therapeutic trials for MDS should continue to be eligible for MDS-type therapy. The clinician should consider such factors as age, antecedent factors, cytogenetics, comorbidities, pace of disease, performance status, and the patient’s goal of treatment. This recommendation is further supported by the results from several validation studies and analyses.²⁶⁻³⁰

The WHO classifications were revised to improve both the diagnostic and prognostic capabilities of these entities. MDS with del(5q) generally has a relatively good prognosis¹⁶ and is highly responsive to lenalidomide therapy.³¹ With a moderate degree of variability, patients with MDS-EB or



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MDS-EB in transformation (MDS-EB-T) generally have a relatively poor prognosis, with a median survival ranging from 5 to 12 months. In contrast, patients with MDS-RS-SLD (RA) or MDS-RS have a median survival of approximately 3 to 6 years. The proportion of these individuals with disease that transforms to AML ranges from 5% to 15% in the low-risk MDS-RS-SLD/MDS-RS group to 40% to 50% in the relatively high-risk MDS-EB/MDS-EB-T group. In a study evaluating time-to-disease evolution, 25% of MDS-EB cases and 55% of MDS-EB-T cases underwent transformation to AML in the first year, increasing to 35% of MDS-EB cases and 65% of MDS-EB-T cases within 2 years.⁴ In contrast, the incidence of transformation for RA was 5% in the first year and 10% within 2 years. None of the patients with MDS-RS developed leukemia within 2 years.

Biologic evidence indicates that similar clinical phenotypes, including lower blast counts, older age, lower white blood cell (WBC) counts, and higher erythroblast counts in bone marrow, are seen in patients with splicing factor (SF) mutations among the MDS-EB, MDS-EB-T, and some AML categories compared with SF-non-mutated cases. This suggests that SF-mutated cases comprised a distinct entity among MDS/AML^{32,33} and that SF-mutant MDS-EB/MDS-EB-T constitutes a related disorder overriding the artificial separation between AML and MDS. AML evolving from MDS (AML-MDS) is often more resistant to standard cytotoxic chemotherapy than is de novo AML, especially those AML cases that do not have *TP53* mutations nor those typical of secondary MDS,³³ which arises without a known antecedent hematologic disorder. High-risk MDS, AML-MDS, and some older patients with AML may have a more indolent clinical course in terms of short-term progression compared with patients who have standard presentations of de novo AML. This emphasizes the need to treat at least some patients with a standard presentation of de novo AML³³ differently than patients with indolent MDS (see [NCCN Guidelines for Acute Myeloid Leukemia](#)).

Myelodysplastic/Myeloproliferative Neoplasms

The category of MDS/MPN was added to the 2008 update of the WHO classification of myeloid neoplasms.³⁴ In the 2022 update, this category includes chronic myelomonocytic leukemia (CMML)-1 and CMML-2, MDS/MPN and neutrophilia (previously aCML), MDS/MPN with *SF3B1* mutation and thrombocytosis (previously MDS/MPN with ring sideroblasts and thrombocytosis), and MDS/MPN NOS (previously MDS/MPN unclassifiable).⁸ (See *MDS/MPN, Classification* in the algorithm). Juvenile myelomonocytic leukemia (JMML) is classified as a myeloproliferative neoplasm.

In the ICC, CMML has been subdivided into two groups based on molecular and clinical differences: CMML-myelodysplastic (WBC count $\leq 13 \times 10^9/L$) and CMML-myeloproliferative (WBC count $> 13 \times 10^9/L$).⁹ In addition to the WBC count, the percentage of blasts plus monocytes in the peripheral blood and bone marrow has demonstrated prognostic significance. Two blast-based groups are included in the WHO 2022 classification: CMML-1 for patients with $< 10\%$ bone marrow blasts or blasts equivalents; and CMML-2 for patients with 10 to $< 20\%$ bone marrow blasts or blasts equivalents.⁸ Mutations in the following genes are frequently associated with CMML: *TET2*, *SRSF2*, *ASXL1*, *RUNX1*, *NRAS*, and *CBL*.^{35,36}

The management of CMML depends on the characteristics of the patient's disease and is typically focused on supportive care and cytoreductive therapy.³⁷ In patients with CMML-1 and CMML-2, decitabine and azacitidine (AzaC) have demonstrated efficacy,³⁷⁻⁴¹ and emerging data suggest utility of ruxolitinib in this context.⁴² Patients with higher-risk IPSS-R and those with lower-risk IPSS-R with poor-risk genetic features, profound cytopenias, and high transfusion burden are candidates for hematopoietic cell transplantation (HCT).^{37,39,43,44} Patients with CMML may have disease that responds to ruxolitinib for symptomatic disease.^{42,45}



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Patients with a t(5;12) translocation associated with the *ETV6::PDGFRβ* fusion gene may respond to imatinib mesylate.^{37,46,47} Patients with CMML may also have systemic mastocytosis with an associated hematologic neoplasm (SM-AHN) and *KIT*816V mutation responsive to midostaurin.^{48,49} Hypomethylating agents (HMAs) or hydroxyurea may be considered for patients with CMML-1. HMAs, with or without venetoclax, and/or allogeneic HCT, is recommended for patients with CMML-2. In non-transplant candidates, the risk of cytopenias with the addition of venetoclax should be carefully considered. Ruxolitinib may be added to HMAs for symptom management or splenomegaly for CMML-2.

MDS/MPN and neutrophilia (termed aCML in the ICC), is rare and has similar neutrophilia as the chronic neutrophilic leukemia (CNL) subtype of MPN. However, molecular characterization may distinguish the two entities. The presence of *CSF3R* mutations is strongly associated with CNL but is present in <10% of cases.^{50,51} Other MPN-associated driver mutations (ie, *JAK2*, *CALR*, *MPL*) are uncommon. The presence of *SETBP1* or *ETNK1* mutations (or both) is reported in up to one third of patients.⁵²⁻⁵⁶ The use of HMAs in MDS/MPN and neutrophilia is a rational application of their established activity in MDS and CMMI.⁵⁷⁻⁵⁹ Emerging data suggest that rare patients with *CSF3R* or *JAK2* mutations may respond to ruxolitinib therapy due to their JAK-STAT pathway activation.^{58,60,61} Although the data on HCT procedures are limited, allogeneic HCT is the only treatment modality that can induce long-term remissions in aCML.^{54,57,58,62} HMAs and/or ruxolitinib and/or allogeneic HCT may be considered for patients with MDS/MPN and neutrophilia.^{57,61}

MDS-RS-T includes patients who present with clinical and morphologic features consistent with MDS and thrombocytosis (platelet counts $\geq 450 \times 10^9/L$).⁶³ The morphology is characterized by MDS-RS features (no blasts in the peripheral blood, dysplastic erythroid proliferation, ring sideroblasts $\geq 15\%$ of erythroid precursors, and <5% blasts in marrow) with proliferation

of large atypical megakaryocytes similar to those seen in essential thrombocythemia or primary myelofibrosis. The frequency of spliceosome gene *SF3B1* mutations in up to 60% of MDS-RS-T cases has resulted in the inclusion of MDS/MPN-RS-T (termed MDS/MPN-T-*SF3B1* or MDS/MPN-RS-T, NOS in the ICC) as a full entity.⁶⁴⁻⁶⁷ *SF3B1* mutations are associated with the presence of ring sideroblasts and frequently have the *JAK2* V617F mutation or *MPL* W515K/L mutation.⁶³ In contrast to MDS-RS, *SF3B1* mutations do not change the required percentage of ring sideroblasts for diagnostic classification. *CALR* mutations have also been reported.⁶⁸ Case reports suggest efficacy of lenalidomide at alleviating the need for red blood cell (RBC) transfusions in patients with MDS/MPN-RS-T.⁶⁸⁻⁷⁰ HMAs and/or lenalidomide⁶⁹; or luspatercept-aamt⁷¹ may be considered. In one study, out of 14 patients with MDS/MPN-RS-T randomized to receive luspatercept, 64.3% achieved RBC-TI of ≥ 8 weeks during weeks 1 to 24, compared to 22.2% out of 9 patients randomized to receive placebo ($P = .028$).⁷¹

MDS/MPN-U (termed MDS/MPN NOS in the ICC) is a rare diagnosis, making up <5% of all myeloid disorders.⁷² This disorder is a myeloid neoplasm with mixed MDS/MPN features at onset, but does not meet the WHO criteria for any other MDS/MPN, MDS, or MPN.⁷³ The diagnostic criteria include: clinical and morphologic features consistent with MDS and thrombocytosis (platelet counts $\geq 450 \times 10^9/L$), and WBC count $\geq 13 \times 10^9/L$. The most frequently mutated genes associated with this subtype include *TET2*, *NRAS*, *RUNX1*, *CBL*, *SETBP1*, and *ASXL1*.^{51,53,73,74} There is no optimal treatment consensus for patients with MDS/MPN-U who are not eligible for allogeneic HCT.⁵⁴ In a series of 85 patients with WHO-defined MDS/MPN-U, most of the patients received HMAs, which was associated with improved overall survival (OS) compared to other treatment approaches (16.4 vs. 11.5 months).^{54,72} These alternate non-transplant approaches included interferon alpha, thalidomide, and lenalidomide.⁷² HMAs and/or allogeneic HCT may be considered.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

MDS/MPN with i(17q) is a provisional entity in the ICC and is characterized by a WBC count $\geq 13 \times 10^9/L$ and dysgranulopoiesis.⁹ Frequent mutations include those in the *SETBP1* and *SRSF2* genes.⁷⁵ The recommended treatment approach is allogeneic HCT.

JMML is a rare childhood cancer that presents in infants and young children. In the 2022 WHO update, it is now classified as an MPN. In the ICC, this is classified as a pediatric disorder and/or germline mutation-associated disorder. Clinical and hematologic criteria for the diagnosis of JMML include: peripheral blood monocyte count $\geq 1 \times 10^9/L$; blast percentage in the peripheral blood and bone marrow $< 20\%$; splenomegaly; and the absence of *BCR::ABL1* rearrangement.⁷³ Although no mutations are exclusive to this disease subtype, the most frequently mutated genes in JMML are *PTPN11* (40%–50%), *NRAS* (15%–20%), *KRAS* (10%–15%), *CBL* (15%–18%), and *NF1* (10%–15%).^{76,77} Secondary mutations in the *SETBP1* and *JAK3* genes were also reported.⁷⁷ In some patients, these mutations may be present as germline variants where they are frequently associated with Noonan syndrome or other congenital syndromes (see *Genes Frequently Somatically Mutated in MDS* in the algorithm). In patients who do not have genetic features of JMML, with at least two of the following must be present: hemoglobin F increased for age; myeloid or erythroid precursors on peripheral blood smear; granulocyte-macrophage colony-stimulating factor (GM-CSF) hypersensitivity in colony assay; and hyperphosphorylation of *STAT5*.^{8,73} Allogeneic HCT is the main treatment option for JMML.^{54,78}

In patients with blastic plasmacytoid dendritic cell neoplasm (BPDCN) skin lesions, approximately 10% to 20% of cases are associated or develop into other myeloid neoplasms, including CMML, MDS, or AML.⁷⁹ Therefore, an accurate pathologic diagnosis is important for patients to receive the best care. Tagraxofusp has been shown to be a potentially useful therapy for these patients.⁸⁰

Hydroxyurea may be helpful in decreasing excessive leukocytosis or thrombocytosis for the subtypes described above (except for BPDCN).⁸¹ For patients with MDS or MDS/MPN overlap syndromes, observation may be considered to document indolent course versus marked progression of severe cytopenia or increase in blasts.

Indolent Myeloid Hematopoietic Disorders

The spectrum of indolent myeloid hematopoietic disorders encompasses four groups: clonal hematopoiesis of indeterminate potential (CHIP); idiopathic cytopenia of undetermined significance (ICUS); lower-risk clonal cytopenia of undetermined significance (CCUS); and higher-risk CCUS. Based on cytopenia(s), dysplasia, clonality, and risk of transformation, patients can be classified within the spectrum (see *Spectrum of Indolent Myeloid Hematopoietic Disorders* in the algorithm). These disorders can evolve into MDS or AML, although the frequency of progression may differ among the four groups.

CHIP and CCUS are defined by the presence of a clonal karyotypic abnormality (present in ≥ 2 metaphases) and/or a somatic mutation in a gene involved in hematopoiesis (present at $> 2\%$ variant allele frequency). There is an absence of marrow dysplasia in these patients. CCUS differs from CHIP by having the presence of cytopenia. Although CHIP is generally benign and has a low likelihood of progression compared to other pre-malignant conditions, there is a higher risk of subsequent hematologic disease compared to patients who do not have somatic mutations.^{82,83} Additionally, shorter survival in these patients compared with aged-matched controls has been demonstrated and may be attributed to non-hematologic causes.⁸³ The most frequently mutated genes associated with CHIP include *DNMT3A*, *TET2*, *ASXL1*, *RUNX1*, *JAK2*, *PPM1D*, *TP53*, and SF genes.⁸³⁻⁸⁵ Patients with pathogenic mutations with $> 10\%$ variant allelic frequency and ≥ 2 somatic mutations, spliceosome gene mutations, or mutations of *RUNX1* or *JAK2* have positive predictive



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

values for myeloid neoplasms (ie, MDS, MPN, AML).⁸⁶ Isolated mutations of *DNMT3A*, *TET2*, and *ASXL1* have less predictive value.⁸⁶ The risk for myeloid neoplasm is increased 3-, 37-, and 348-fold in low-risk, intermediate-risk, and high-risk CHIP/CCUS, respectively, compared to unmutated controls.⁸⁷ ICUS has no known cause, lack somatic mutations or clonal karyotypic abnormalities. There is significant heterogeneity within ICUS, with some patients experiencing spontaneous resolution of disease and others developing a myeloid neoplasm.⁸⁸ Data are limited regarding natural history and disease progression for these two disorders. An online calculator should be considered to obtain a clonal hematopoiesis risk score with a corresponding risk category (low, intermediate, or high), as these risk groups significantly differ in the 10-year probabilities of developing myeloid neoplasms, as well as OS.⁸⁷

Two studies have focused on the role of mutational analysis in indolent malignant disease. In a prospective analysis of 144 patients, Kwok and colleagues⁸⁹ used a 22-gene panel to determine the frequency of MDS-associated mutations. Among these patients, 17% were categorized as MDS, 15% as ICUS with mild dysplasia, and 69% as ICUS without dysplasia. Further analysis showed that 35% of patients with ICUS had a somatic mutation or chromosomal abnormality similar to MDS; these patients were characterized as CCUS. The similar mutational features may have a role in the diagnostic value of these disorders.⁸⁹

Cargo et al⁸⁸ evaluated mutational features associated with ICUS in patients with disease that developed into progressive dysplasia or AML. Although this study was not designed to evaluate the diagnostic role of mutations, detection of mutational features predicted progression to high-risk disease and OS. The study proposes that patients who are defined as poor-risk may benefit from early intervention.

NCCN recommends that following the initial evaluation, regular monitoring of blood counts in patients with these indolent myeloid hematopoietic

disorders occur at least every 3 to 6 months. More frequent monitoring may be recommended based on clinical expertise. Observation is the recommended clinical approach. Monitoring is recommended for CHIP (based on clinical change), ICUS (yearly), lower-risk CCUS (yearly), and high-risk CCUS (CBC 2 to 4 times yearly). Enrollment in a clinical trial should be considered for high-risk CCUS.

Childhood MDS

Several differences exist between adult and childhood myelodysplasia. MDS and myelodysplasia are quite rare in children, occurring in 1 to 4 cases per million per year with a median age of 6.8 years.⁹⁰⁻⁹² MDS in children is strongly associated with congenital disorders.⁹³ Genetic syndromes are evident in 50% of cases, including Down syndrome,⁹⁴⁻⁹⁶ trisomy 8 syndrome,⁹⁷ Fanconi anemia,^{98,99} congenital neutropenia (Kostmann syndrome),^{100,101} Diamond-Blackfan anemia,¹⁰² Shwachman-Diamond syndrome,¹⁰³ dyskeratosis congenita (DC),¹⁰⁴ neurofibromatosis type 1,¹⁰⁵ Bloom syndrome,^{106,107} Noonan syndrome,¹⁰⁸ and Dubowitz syndrome.¹⁰⁹ Prior exposure to cytotoxic therapy (eg, alkylating agents, epipodophyllotoxins, topoisomerase II inhibitors)¹¹⁰⁻¹¹³ or radiation^{114,115} increases the risk for MDS.

The 2022 WHO classification identifies 2 childhood myelodysplastic neoplasms: Childhood MDS with low blasts (previously termed refractory cytopenia of childhood [RCC]) and childhood MDS with increased blasts.⁸ RCC is the most common subtype of MDS found in children, accounting for approximately 50% of cases.⁹² Abnormal karyotypes are found in 30% to 50% of children with MDS,¹¹⁶ most common are numerical anomalies with <10% showing structural abnormalities. Monosomy 7 is the most common cytogenetic abnormality, occurring in 30% of cases,^{117,118} followed by trisomy 8^{119,120} and trisomy 21.¹²¹ The del(5q) abnormality is rarely seen in children.¹²² Clinically, isolated RAs are uncommon in children. Thrombocytopenia and/or neutropenia, often accompanied by



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

hypocellular marrow, is a common presentation. Fetal hemoglobin levels are frequently elevated.

Differential diagnoses include aplastic anemia (AA) and AML. Compared to AA, children with MDS have a significantly elevated mean corpuscular volume; clonal hematopoiesis is confirmatory. Higher expression of *p53*, lower expression of survivin, or the presence of MDS-related cytogenetic abnormalities can also help differentiate MDS from AA.¹²³ Compared with AML, low WBC count, multi-lineage dysplasia, and clonal hematopoiesis with numerical, rather than structural, cytogenetic abnormalities suggest MDS. A bone marrow blast count of <20% also suggests MDS, but biologic features are more important than a strict blast cutoff value. Monosomy 7 strongly suggests MDS. When patients present with AML, the marrow frequently shows dysplastic features, but this does not necessarily indicate that the AML arose after MDS. Indeed, criteria for the diagnosis of MDS in a patient who presents with AML are stringent.¹²⁴ Dysplasia in bone marrow cells may also be due to other etiologies including infection (eg, Parvo virus,^{125,126} herpes viruses,¹²⁷ HIV), deficiencies of B₁₂ and copper,¹²⁸ drug therapy, and chronic disease.¹²⁹ Congenital dyserythropoietic anemia, congenital sideroblastic anemia, and Pearson syndrome should also be excluded.

Children with Down syndrome have an increased risk of developing leukemia (50-fold greater risk if younger than 5 years), and are usually categorized as having acute megakaryoblastic leukemia (AMKL, M7).^{94,96,130,131} This commonly has a prodromal phase of cytopenia(s) similar to MDS and may be considered a spectrum of the same disease. Prognosis of patients with Down syndrome and AMKL is quite good with an 80% cure rate when treated with intensive chemotherapy. HCT is not indicated in first complete remission for these children. Newborns with Down syndrome can develop abnormal myelopoiesis with leukocytosis, circulating blasts, anemia, and thrombocytopenia, but this resolves

spontaneously within weeks to months. Approximately 20% of children with Down syndrome, who have transient abnormal myelopoiesis, will subsequently develop AMKL.⁹⁵

There is a paucity of clinical trials due to the rarity and heterogeneity of MDS in children. The primary goal of treatment is generally a cure rather than palliation. HCT is the only curative option in childhood MDS with 3-year disease-free survival rates of approximately 50%.¹³²⁻¹³⁴ Myeloablative therapy with busulfan, cyclophosphamide, and melphalan, followed by either matched family or matched unrelated donor allogeneic HCT is the treatment of choice for children with MDS. Other treatments such as chemotherapy, growth factors, and immunosuppressive therapy (IST) have a limited role. Prognosis for untreated MDS depends on the rate of progression to AML. The stage of the disease at the time of HCT strongly predicts outcome.¹¹⁸

Patients with RCC have a median time to progression to advanced MDS of 1.7 years,¹¹⁸ but the time to progression is highly variable, depending on the underlying cause of MDS and standard prognostic factors.¹³⁵ Patients with JMML have a variable prognosis; some younger patients with favorable genetics and clinical features have resolution of JMML without treatment, while others progress rapidly despite allogeneic HCT.¹³⁶ Children diagnosed before age 2 years have the best prognosis. Poor prognostic features include high hemoglobin F, older age, and thrombocytopenia.

Pediatric AML or MDS with monosomy 7 has a poor prognosis with conventional therapies. A review of 16 patients with AML and MDS with monosomy 7 treated by two transplant programs from 1992 to 2003 (MDS, n = 5; therapy-related MDS [t-MDS], n = 3; AML, n = 5; therapy-related AML [t-AML], n = 3) reported a 2-year event-free survival of 69%.¹³⁷ Four of the five deaths occurred in patients transplanted with active leukemia. Seven of eight patients with MDS were alive without



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

evidence of disease (six in first complete remission, one in second complete remission, and one death due to complications).¹³⁷

Although MDS can occur in both adult and pediatric populations, the treatment strategies and recommendations are not necessarily the same. The NCCN Guidelines for Myelodysplastic Syndromes focus on recommendations for the diagnosis, evaluation, and treatment of adult patients with MDS; therefore, the discussions that follow pertain to adult patients.

Evaluation

Several types of evaluations are needed to determine the clinical status of patients with MDS. Understanding clinical status is necessary for diagnostic and prognostic categorization and to determine treatment options.

Initial Evaluation

Clinical history should include the timing, severity, and tempo of abnormal cytopenias; prior infections or bleeding episodes; and number of transfusions. Cytopenias are defined as values lower than standard laboratory hematologic levels, being aware of age, sex, ethnic, and altitude norms.¹² Concomitant medications and comorbid conditions require careful assessment. Because MDS are relatively indolent disorders, blood count stability is used to distinguish MDS from evolving AML. Other possible causes of cytopenias require careful evaluation.

In addition to establishing current blood and reticulocyte counts, clinicians need a peripheral blood smear evaluation to determine the degree of dysplasia and, thus, potentially dysfunctional cells. Bone marrow aspiration with Prussian blue stain for iron and a biopsy are needed to evaluate the degree and relative proportions of hematopoietic cell maturation abnormalities, percentage of marrow blasts, marrow cellularity,

presence or absence of ring sideroblasts (and presence of iron per se), and fibrosis. Cytogenetics for bone marrow samples (by standard karyotyping methods) should be obtained, because they are of major prognostic importance. If standard cytogenetics with 20 or more metaphases cannot be obtained, chromosome microarray analysis (CMA)/chromosome genomic array testing (CGAT)⁶¹ or MDS-related FISH panel should be performed. If karyotype is normal, the CMA should be considered. However, CMAs detect both somatic and germline or constitutional changes.

Bone marrow biopsy staining for reticulin is recommended for evaluating the presence and degree of bone marrow fibrosis.¹³⁸ Increased reticulin fibers in the marrow at diagnosis are seen in approximately 5% to 10% of MDS cases.¹³⁹⁻¹⁴² MDS with fibrosis is considered a distinct subtype of MDS in the 2022 WHO classification.⁸ These patients frequently present with severe pancytopenia and decreased survival in these patients has been reported.^{139,140}

Other useful recommended laboratory screening tests include serum erythropoietin (sEPO), vitamin B₁₂, RBC folate levels, serum ferritin, iron, and total iron-binding capacity (TIBC). RBC folate and serum folate levels should not be considered equivalent, and RBC folate is preferred. RBC folate levels are more indicative of folate stores, whereas serum folate levels are reflective of recent nutrition. However, if RBC folate cannot be evaluated, serum folate should be considered as an alternative, although clinicians should be advised of the limitations. Serum ferritin levels may be nonspecific, particularly in inflammatory conditions such as rheumatoid arthritis. In such cases, obtaining the serum iron levels and TIBC along with serum ferritin may be helpful. As hypothyroidism and other thyroid disorders can lead to anemia, patients should also be evaluated for levels of thyroid-stimulating hormone.¹⁴³ HIV testing should also be performed, if clinically indicated.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Elevated levels of lactate dehydrogenase (LDH) are predictive of a decreased survival. LDH is a measure of the systemic inflammation that occurs as a result of tissue turnover or hemolysis. The IPSS and IPSS-R identified LDH as a prognostic feature and other studies have supported the association. In a retrospective study, LDH levels taken at diagnosis were stratified in patients with disease categorized as IPSS-R intermediate. Patients with LDH levels ≥ 320 U/L ($n = 8$) had a significantly shorter overall OS than patients with levels below 320 U/L ($n = 28$; 347 days vs. 1339 days, respectively; $P = .03$).¹⁴⁴

There have been reports that copper deficiency can mimic many of the peripheral blood and marrow findings seen in MDS.¹⁴⁵⁻¹⁴⁷ Copper deficiency is an etiology of anemia, neutropenia, and bone marrow dysplasia that may be under-recognized. There are rare cases of patients with clinical presentation consistent with MDS who may be deficient in copper and for whom copper supplementation may resolve hematologic abnormalities. Copper and ceruloplasmin level assessments should be considered as part of the initial diagnostic workup in patients suspected of having low-risk MDS, especially those with gastrointestinal (GI) disorders and neuropathy.¹⁴⁸ Clinical features associated with copper deficiency include vacuolation of myeloid and/or erythroid precursors,¹⁴⁵⁻¹⁴⁷ prior GI surgery,^{145,146} a history of vitamin B₁₂ deficiency,^{146,149} severe malnutrition, and a history of zinc supplementation.

Bone marrow or peripheral blood cells should be assayed for somatic mutations in genes associated with MDS (see *Genes Frequently Somatically Mutated in MDS* in the algorithm) as these gene mutations may be clinically useful in specific contexts. For example, mutations in splice factor genes are much more common in patients with MDS, MDS-SF3B1, and CMML compared to other myeloid neoplasms. Approximately 40% of patients with MDS will carry a mutation in one of the three most frequently mutated splice factors: SF3B1, SRSF2, and U2AF1.¹⁵⁰ A typical

mutation in one of these genes indicates the presence of clonally derived hematopoiesis and may help determine diagnosis in the appropriate clinical context.

Mutations of SF3B1 are associated with the presence of ring sideroblasts and are highly prevalent in patients with MDS-RS or MDS-RS-T (>80%).⁶⁵ Mutations of JAK2 are found in 50% of patients with MDS-RS-T, although it is much rarer in other subtypes. Mutations of SRSF2 are enriched in patients with CMML, although it is not unique to this subtype. Patients with JMML will often have mutations in one of the tyrosine kinase signaling genes such as PTPN11, NF1, NRAS, KRAS, or CBL.⁷⁷ In many cases, these mutations are congenital and part of a larger syndrome.

Typical mutations in other genes (see *Genes Frequently Somatically Mutated in MDS* in the algorithm) can also establish the presence of clonal hematopoiesis, but they are less specific for disease subtype. Of note, several mutated genes associated with MDS (eg, TET2, DNMT3A, SF3B1, EZH2, NRAS, BRAF, TP53) can be mutated in other neoplasms, including lymphoid malignancies. Rare patients can have dual diagnoses (eg, MDS and chronic lymphocytic leukemia), which can confound the interpretation of sequencing results. Therefore, the presence of mutations must be interpreted in an appropriate clinical context consistent with MDS. Acquired mutations of TET2 and DNMT3A are frequent in MDS but have also been identified in older persons with clonal hematopoiesis and normal blood counts. Whether mutations of these or other genes are predictive of MDS in patients with cytopenias who do not meet morphologic diagnostic criteria for MDS is not known. Therefore, somatic mutations should not be used as presumptive evidence of MDS in the absence of other diagnostic features. Patients with cytopenias who lack bone marrow findings diagnostic of MDS can have somatic mutations indicative of clonal hematopoiesis, and as indicated above, those with pathogenic mutations with >10% variant allelic frequency and ≥ 2 somatic mutations,



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

spliceosome gene mutations, or mutations of *RUNX1* or *JAK2* have positive predictive values for myeloid neoplasms (ie, MDS, MPN, AML).⁸⁶ The mere presence of a mutation is not a substitute for the pathologic diagnosis of MDS (ie, requiring dysplasia) and should not be used as the sole indication for treatment. Mutations in some non-MDS genes may indicate the presence of neoplasms that can mimic MDS. These include *CALR* mutations associated with primary myelofibrosis, *CSF3R* mutations associated with aCML and CNL, and *STAT3* mutations associated with large granular lymphocyte (LGL) leukemia.

For discussion regarding the prognostic value of molecular abnormalities, see *Molecular Abnormalities in MDS*.

Additional molecular and genetic screening for heritable hematologic malignancy predisposition is recommended in a subset of patients, particularly in patients <50 years of age. Diseases, syndromes, and mutations that may potentially be associated include *GATA2* deficiency syndrome, Shwachman-Diamond syndrome, short telomere syndromes, *DDX41* mutations (usually present at older ages), and others (see *Genetic Familial High-Risk Assessment: Hereditary Myeloid Malignancy Predisposition Syndromes* and see *Gene Mutations Associated with Hereditary Myeloid Malignancies* in the algorithm). Shortened telomere length has been associated with diseases of bone marrow failure, including inherited disorders such as dyskeratosis congenita, particularly in the presence of mutations in the *DKC1*, *TERT*, or *TERC* genes that encode for components of the telomere complex.^{151,152} Telomere length can be measured by FISH assays using leukocyte (or leukocyte subset) samples.^{151,153} Other genetic lesions, such as those occurring in the *RUNX1* or *GATA2* gene, have been implicated in familial cases of MDS and other myeloid malignancies.

Lesions within the *RUNX1* gene (mutations, deletions, or translocations) have been identified as one cause of a relatively rare autosomal-dominant

familial platelet disorder that predisposes these patients to myeloid malignancies.^{154,155} In affected families with the *RUNX1* lesions, the incidence of MDS/AML is high, ranging from 20% to 60% in which the median age of onset is 33 years.¹⁵⁶ This familial platelet disorder is characterized by the presence of thrombocytopenia, and a tendency for mild-to-moderate bleeding generally presents from childhood; however, some affected individuals may not display these clinical characteristics.¹⁵⁶ Different types of genetic lesions in *RUNX1* account for the variable phenotypes associated with familial platelet disorder between different families. Cryptic genetic lesions in *RUNX1* have been reported in some patients with Fanconi anemia and MDS/AML.¹⁵⁷ Identification of Fanconi anemia is clinically important, because it is associated with chromosomal fragility that results in variability of disease response to HMAs.

The *GATA2* gene codes for a transcription factor involved in gene regulation during the development and differentiation of hematopoietic cells and its expression was shown to correlate with severe dysplasia in patients with primary MDS.¹⁵⁸ Heritable mutations in *GATA2* were identified in families with highly penetrant, early-onset MDS and/or AML.¹⁵⁹ The mutations showed an autosomal-dominant pattern of inheritance, and affected individuals with this familial form of MDS/AML had poor outcomes in the absence of allogeneic HCT.¹⁵⁹ More importantly, family members may not be eligible as donors for allogeneic HCT.

Additional Testing

For HCT candidates, cytomegalovirus (CMV) status and full human leukocyte antigen (HLA) typing (A, B, C, DR, and DQ) of the patient and potential donors are needed. Flow cytometry for assessing the percentage of blast cells in the bone marrow (as measured by the cell surface expression of CD34) may also be valuable in some clinical situations, including detection of LGL disease. It should be emphasized, however, that estimates of blast percentage by flow cytometry do not



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

provide the same prognostic information as the blast percentage derived from morphologic evaluation. Accordingly, flow cytometry data should not be used in lieu of the determination of morphologic blast percentage by an experienced hematopathologist. Flow cytometry may be considered as a diagnostic aid for MDS and may be considered along with *TCR* polymerase chain reaction and *STAT3* mutation testing to evaluate for LGL and paroxysmal nocturnal hemoglobinuria (PNH) clone.

The screening for PNH or *STAT3*-mutant cytotoxic T-cell clones is potentially useful for determining which patients may be more responsive to IST, particularly young patients with normal cytogenetics and hypoplastic MDS^{160–162} (see *Prognostic Stratification*). PNH is a rare, acquired disorder of the blood arising from mutations in the *PIG-A* gene resulting in defective synthesis of the glycoprophosphatidylinositol (GPI) anchor. This, in turn, leads to a deficiency of proteins that are normally linked to the cell membrane of blood cells via a GPI anchor.^{163–166} Deficiency in GPI-anchored proteins such as those involved in complement inhibition (eg, CD55, CD59) leads to complement sensitivity of RBCs and subsequent hemolysis.^{163,164} Flow cytometry is the established method for detecting GPI-anchor-deficient cells for the diagnosis of PNH. Fluorescent aerolysin (FLAER), a protein that specifically binds to GPI anchors, has been shown to be a highly specific and reliable marker for detecting GPI-anchor-deficient clones among granulocytes or monocytes.¹⁶⁷ For evaluation of PNH clonogenicity, multiparameter flow cytometry analysis of granulocytes and monocytes using FLAER, and at least one GPI-anchored protein, should be considered.^{163,164,167} It should be emphasized that although evidence of a minor PNH clone may be present in approximately 20% of patients with MDS, there is usually no evidence of PNH-related hemolysis in these patients.

Cases of patients with myelodysplastic features and clonal expansion of LGLs have been reported.^{168–171} In one of these studies, three out of nine patients responded to IST as indicated by improved blood counts.¹⁶⁸ Although patients with both MDS and LGL did not respond as well as patients with LGL (33% vs. 66%; $P = .01$), the presence of the T-cell clone may reflect a target for IST. A second study reported improved outcomes in 61 patients with MDS with LGL clonogenicity receiving anti-thymocyte globulin (ATG).¹⁶⁹ Moreover, the MDS-SLD refractory anemia (RA) subtype was determined as a favorable predictor of response compared to patients with non-MDS-SLD RA (odds ratio [OR], 0.15; 95% CI, 0.04–0.59; $P = .005$).¹⁶⁹

In addition to basic flow cytometric evaluation at presentation for characterization of blasts and evaluation of lymphoid populations, expanded flow cytometry may be a useful adjunct for diagnosis of MDS in difficult cases. In expert hands (both in terms of technical sophistication and interpretation), flow cytometry may demonstrate abnormal differentiation patterns or aberrant antigen expression in myeloid or progenitor cells, which may help confirm a diagnosis of MDS, exclude differential diagnostic possibilities, and, in some patients, provide prognostic information.^{172–176} Flow analysis should use appropriate antibody combinations with four fluorescence channel instrumentation.^{172–176} Multiple aberrancies should be present for the diagnosis of MDS, as single aberrancies are not infrequent in normal populations. For follow-up studies, antibody combinations may be tailored to detect specific abnormalities implicated in the initial evaluation. While aberrancies have also been described in erythroid cells, most flow cytometry laboratories do not provide erythroid analysis.

The European LeukemiaNET developed a flow cytometric score based on the reproducible parameters of CD34 and CD45 markers to aid in the diagnosis of MDS.¹⁷⁷ The scoring system was developed using multicenter



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

retrospective data from patients with low-grade MDS (defined as <5% marrow blasts; n = 417) and patients with non-clonal cytopenias as controls (n = 380). This patient population was selected because low-grade MDS often lack specific diagnostic markers (eg, ring sideroblasts, clonal cytogenetic abnormalities), which makes it difficult to diagnose based on morphology alone. Bone marrow samples from patients with MDS compared with samples from patients with non-clonal cytopenias showed different flow cytometric patterns, including: 1) increased CD34+ myeloblast-related cluster size (defined by a wider distribution of CD45 expression and greater side scatter [SSC] characteristics); 2) decreased CD34+ B-progenitor cluster size (defined by a relatively low CD45 expression and low SSC); 3) aberrant myeloblast CD45 expression (based on the lymphocyte to myeloblast CD45 ratio); and 4) a decreased granulocyte SSC value (based on the granulocyte to lymphocyte SSC ratio).¹⁷⁷ These four parameters were included in a logistic regression model, and a weighted score (derived from regression coefficients) was assigned to each parameter. The sum of the scores provided the overall flow cytometric score for each sample, with a score of 2 or higher defined as the threshold for MDS diagnosis.¹⁷⁷ Using this flow cytometric score in the learning cohort, a correct diagnosis of MDS was made with 70% sensitivity and 93% specificity. Among patients with MDS without specific markers of dysplasia, 65% were correctly identified. The positive predictive and negative predictive values were 92% and 74%, respectively. These outcomes were confirmed in the validation cohort, which showed 69% sensitivity and 92% specificity.¹⁷⁷ This flow cytometric scoring system demonstrated a high diagnostic power in differentiating low-grade MDS from non-clonal cytopenias, and may be particularly useful in establishing a diagnosis in situations where traditional diagnostic methods are indeterminate. Further independent validation studies are warranted to determine the utility of this method.

Because of the associated expense, the requirement for both technical and interpretational expertise, and the need for greater consensus on specific antibody combinations and procedures that are most informative and cost-effective, flow cytometric assays should be performed by experienced laboratories and used in general practice only when diagnosis is uncertain with traditional approaches (eg, blood counts, morphology, cytogenetics, increased blasts). Flow cytometry studies may also be used to assess the possibility of LGL disease, as indicated by LGLs present in the peripheral blood.¹⁷⁸ In addition, STAT3 mutations are commonly found in T-LGL disease.¹⁷⁹

Determination of platelet-derived growth factor receptor beta (*PDGFRβ*) gene rearrangements at 5q32 may be helpful to evaluate in patients with CMML.¹⁸⁰ The activation of this gene encoding a receptor tyrosine kinase for *PDGFRβ* has been identified in some of these patients.^{181,182} Data have shown that patients with CMML/MPD with *PDGFRβ* rearrangement may respond well to treatment with the tyrosine kinase inhibitor imatinib mesylate.^{46,183,184}

Evaluation of Related Anemia

Major morbidities of MDS include symptomatic anemia and associated fatigue. Progress has been made in the management of MDS-related anemia; however, the health care provider must also identify and treat any coexisting causes of anemia. Standard assessments should be performed to look for other causes of anemia, such as GI bleeding, hemolysis, renal disease, and nutritional deficiency. If needed, iron, folate, or vitamin B₁₂ studies should be obtained and the cause of depletion corrected, if possible. After excluding or providing proper treatment for these causes of anemia, further consideration for treating MDS-related anemia should be undertaken. Anemia related to MDS commonly presents as a hypoproliferative macrocytic anemia, often associated with suboptimal



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

elevation of sEPO levels.^{4,185} Bone marrow aspiration with iron stain, biopsy, and cytogenetics should be used to determine WHO subtype, iron status, and the level of ring sideroblasts.

Prognostic Stratification

Although the diagnostic criteria allow for categorization of patients with MDS, the highly variable clinical outcomes within these subgroups indicate prognostic limitations. The morphologic features contributing to this variability include the wide range of marrow blast percentages for patients with MDS and CMML (1%–19%); marrow cytogenetics; and the degree and number of morbidity-associated cytopenias. These well-perceived problems for categorizing patients with MDS have led to the development of additional risk-based stratification systems.^{186,187}

Prognostic Scoring Systems

IPSS

The IPSS for primary MDS emerged from deliberations of the International MDS Risk Analysis Workshop (IMRAW).¹⁶ Compared with previous classification systems, the risk-based IPSS markedly improved prognostic stratification of MDS cases. The IPSS was developed based on the combined cytogenetic, morphologic, and clinical data from a relatively large group of MDS cases included in previously reported prognostic studies.^{16,186} FAB morphologic criteria were used to establish the diagnosis of MDS. In addition, relative stability of peripheral blood counts for 4 to 6 weeks was needed to exclude other possible etiologies for the cytopenias, such as drugs, other diseases, or incipient evolution to AML. CMML was subdivided into proliferative and non-proliferative subtypes. Patients with proliferative-type CMML (those with WBC counts >12,000/mcL) were excluded from this analysis.¹⁶ Patients with non-proliferative CMML (with WBC counts of ≤12,000/mcL plus other features of MDS) were included.¹⁸⁸

Significant independent variables for determining survival and AML evolution outcomes were marrow blast percentage, number of cytopenias, and cytogenetic subgroup (good, intermediate, and poor). Patients with the chromosome anomalies t(8;21) or inv(16) were considered to have AML and not MDS, regardless of the blast count. Age was also a critical variable for survival, although not for AML evolution. The percentage of marrow blasts was divisible into four categories: 1) <5%; 2) 5% to 10%; 3) 11% to 20%; and 4) 21% to 30%.

Cytopenias were defined for the IPSS as a hemoglobin level <10 g/dL, an absolute neutrophil count below 1800 cells/mcL, and a platelet count below 100,000 cells/mcL. Patients with normal marrow karyotypes, del(5q) alone, del(20q) alone, and -Y alone had relatively good prognoses (70%), whereas patients with complex abnormalities (three or more chromosome anomalies) or chromosome 7 anomalies had relatively poor prognoses (16%). The remaining patients were classified as having intermediate outcome (14%). Of the patients in the “complex” category, the vast majority had chromosome 5 or 7 abnormalities in addition to other anomalies.

To develop the IPSS for MDS, relative risk scores for each significant variable (marrow blast percentage, cytogenetic subgroup, and number of cytopenias) were generated.¹⁶ By combining the risk scores for the three major variables, patients were stratified into four distinctive risk groups in terms of both survival and AML evolution: low, intermediate (int)-1, int-2, and high. When either cytopenias or cytogenetic subtypes were omitted from the classification, discrimination among the four subgroups was much less precise. Both for survival and AML evolution, the IPSS showed statistically greater prognostic discriminating power than earlier classification methods.¹⁶



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

IPSS-R

The IPSS-R defines five risk groups (very low, low, intermediate, high, and very high) versus the four groups in the initial IPSS.¹⁸⁹ The IPSS-R, which was derived from an analysis of a large dataset from multiple international institutions, refined the original IPSS by incorporating the following into the prognostic model: more detailed cytogenetic subgroups, separate subgroups within the “marrow blasts <5%” group, and a depth of cytopenias measurement defined with cutoffs for hemoglobin levels, platelet counts, and neutrophil counts. In the IPSS-R, the cytogenetic subgroups comprise five risk groups (vs. three in the original IPSS) based on a cytogenetic scoring system for MDS published in 2012.¹⁷ Other parameters including age, performance status, serum ferritin, LDH, and beta-2 microglobulin provided additional prognostic information for survival outcomes, but not for AML evolution; age was more prognostic among lower-risk groups compared with the higher-risk groups.¹⁸⁹ The predictive value of the IPSS-R was validated in a number of independent studies based on registry data, including studies that evaluated outcomes for patients treated with HMAs.¹⁹⁰⁻¹⁹⁵

In a multiregional study of MDS patient registry data from Italy (N = 646), significant differences in outcomes among the IPSS-R risk categories were found for OS, AML evolution, and progression-free survival (PFS) (later defined as leukemic evolution or death from any cause).¹⁹⁶ Notably, the predictive power (based on Harrell's C statistics) of the IPSS-R was found to be greater than the IPSS, WPSS, and refined WPSS for the three outcome measures mentioned above. The investigators acknowledged the limitation of a short follow-up (median, 17 months) in the study cohort.¹⁹⁶

In a retrospective analysis of data from lower-risk MDS (IPSS low or int-1) patients in a large multicenter registry (N = 2373) in Spain, the IPSS-R could identify three risk categories (very low, low, intermediate) within the IPSS low-risk group with none of the patients categorized as IPSS-R high

or very high.¹⁹⁴ Within the IPSS int-1-risk group, the IPSS-R further stratified patients into four risk categories (very low, low, intermediate, high) with only one patient categorized as very high risk. Within the IPSS low-risk group, median survival based on the IPSS-R risk categories was 118.8 months for very low, 65.9 months for low, and 58.9 months for intermediate. Within the IPSS int-1 risk group, median survival based on the IPSS-R risk categories was 113.7 months for very low, 61.3 months for low, 30.4 months for intermediate, and 21.2 months for high risk. This study also applied the refined WPSS to further stratify the IPSS low and int-1 risk groups, and identified a group of patients (refined WPSS high-risk group) within the IPSS int-1 group who had poorer prognosis. However, the IPSS-R identified a larger proportion of patients with poor-risk IPSS int-1 MDS than the refined WPSS (47% vs. 17%).

In a retrospective database analysis of patients with MDS from a single institution (N = 1088), median OS according to IPSS-R risk categories was 90 months for very-low-, 54 months for low-, 34 months for intermediate-, 21 months for high-, and 13 months for very-high-risk groups ($P < .005$).¹⁹³ The median follow-up in this study was 70 months. IPSS-R was also predictive of survival outcomes among the patients who received therapy with HMAs (n = 618). Compared to patients not receiving AzaC, a significant survival benefit with AzaC was shown only for the groups of patients with very-high-risk (median survival, 18 vs. 25 months, respectively; $P < .028$) and high-risk IPSS-R (median survival, 15 vs. 9 months, respectively; $P = .005$). In addition, significantly longer OS with allogeneic HCT was only observed for patients at high (median survival, 40 vs. 19 months without HCT; $P < .005$) and very high (median survival, 31 vs. 12 months without HCT; $P < .005$) risk.¹⁹³ The IPSS-R may therefore provide a tool for therapeutic decision-making.

One study applied the IPSS-R to a series of patients with t-MDS and oligoblastic t-AML (ot-AML).¹⁹⁷ Although some IPSS-R cutpoints were



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

suboptimal for patients with t-MDS/ot-AML, the overall IPSS-R scores separated patients with t-MDS/ot-AML into five risk groups, with each category showing statistical differences in OS as well as AML progression probability in t-MDS. These findings indicated that the major IPSS-R variables (bone marrow blast count, cytopenias, and cytogenetic data) remained powerful predictors in the therapy-related setting. However, compared to de novo MDS/oligoblastic AML, the median OS for each IPSS-R risk group of patients was shorter in t-MDS/ot-AML, particularly in the very-low- and low-risk groups. These differences likely reflect a number of factors, including different biology and clinical approaches (eg, treatment, primary disease, and its therapies) between t-MDS/ot-AML and de novo disease. Data from the MDS Clinical Research Consortium similarly demonstrated the improved prognostic value of the IPSS-R in 370 patients with t-MDS compared to the IPSS, the global MD Anderson risk model, or the t-MDS MD Anderson model.¹⁹⁸ Further studies are warranted to better evaluate the impact of specific therapies and more refined variables and their cut points for analysis of this heterogeneous group of patients.

Other studies have confirmed the value of the IPSS-R in treated as well as untreated patients.^{195,199-201} Since more accurate risk stratification by the IPSS-R compared to the IPSS and WPSS has been demonstrated,¹⁹⁹ the IPSS-R categorization is preferred, although other systems have good value. It is understood that some ongoing studies are using the IPSS or WPSS. Thus, a transition period is expected before more uniform prognostic risk stratification is accepted by the field. An analysis of patients in the International Working Group (IWG) for the Prognosis of MDS database, which generated the IPSS-R, indicated that optimal prognostic separation of lower versus higher-risk MDS was obtained by a dichotomization based on 3.5 scoring points of the IPSS-R raw score (ie, ≤ 3.5 vs. > 3.5).²⁰²

WPSS

Data have indicated a benefit to the addition of other clinical variables to the IPSS to improve the accuracy of prognosis. The WHO classification-based prognostic scoring system (WPSS) incorporates the WHO morphologic categories, the IPSS cytogenetic categories, and the degree of RBC transfusion dependence.²⁰³ This system demonstrated that the requirement for RBC transfusions is a negative prognostic factor for patients in the lower-risk MDS categories. In addition, depth of anemia per se has additive and negative prognostic importance for the intermediate IPSS categories.²⁰⁴ As compared with the four groups defined by the IPSS, the WPSS classifies patients into five risk groups differing in both survival and risk of AML. The five risk groups are: very low, low, intermediate, high, and very high. Following the initial report by Malcovati et al,²⁰³ there have been confirmatory studies demonstrating the usefulness of the WPSS.²⁰⁵⁻²⁰⁷ The initial WPSS has been refined to address the notion that the requirement for RBC transfusion may be somewhat subjective. In the refined WPSS, the measure of the degree of anemia by transfusion dependency is replaced by the presence (or absence) of severe anemia, defined as hemoglobin levels < 9 g/dL for males and < 8 g/dL for females.²⁰⁸ This approach allows for an objective assessment of anemia, while maintaining the prognostic implications of the five risk categories defined in the original WPSS (as mentioned above).²⁰⁸

IPSS-M

The international prognostic scoring system molecular (IPSS-M) is a prognostic model that takes into account blood counts, marrow blasts, IPSS-R cytogenetic risk categories, 16 main effect genes, and 15 residual genes and provides times estimates for OS, LFS, and AML transformation.²⁰⁹ Data from 2957 patients with MDS, including those with secondary or therapy-related MDS and MDS/MPN overlap syndromes, were used to identify six risk categories (very low, low, moderate low,



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

moderate high, high, very high). The median OS was 10.6 years for the very low risk category, 6.0 for low risk, 4.6 for moderate low risk, 2.8 years for moderate high risk, 1.7 for high risk, and 1.0 for very high risk. The median LFS was 9.7 (very low risk), 5.9 (low risk), 4.5 (moderate low risk), 2.3 (moderate high risk), 1.5 (high risk), and 0.76 years (very high risk) respectively. The model was validated in a cohort of 754 Japanese patients. The Panel notes that the IPSS-M may have a role in improving clinical decision-making but requires confirmatory evidence to help assess its efficacy.

LR-PSS

The Lower-Risk Prognostic Scoring System (LR-PSS), is a prognostic model used in the evaluation of MDS, and was designed to help identify patients with lower-risk disease (IPSS low or int-1) who may have a poor prognosis.²¹⁰ The prognostic model was developed using clinical and laboratory data from patients with IPSS low- (n = 250) and int-1- (n = 606) risk MDS. Factors associated with decreased survival were identified and a prognostic model was constructed based on the results of multivariate Cox regression analysis. The final model included the following factors that were independent predictors for survival outcomes: unfavorable cytogenetics, older age (≥ 60 years), decreased hemoglobin (< 10 g/dL), decreased platelet count ($< 200 \times 10^9/L$), and higher percentage of bone marrow blasts ($\geq 4\%$). Importantly, the cytogenetic categories in this system were derived from the previously defined IPSS categories rather than from the more refined IPSS-R. Each of these factors was given a weighted score, and the sum of the scores (range, 0–7 points) was used to generate three risk categories: a score of 0 to 2 points was assigned to category 1, a score of 3 or 4 was assigned to category 2, and a score of 5 to 7 was assigned to category 3. Using this scoring system, median survival was 80.3 months for category 1, 26.6 months for category 2, and 14.2 months for category 3; the 4-year survival rates were 65%, 33%, and 7%, respectively. The scoring system allowed for further stratification into

these three risk categories for both the IPSS low-risk and IPSS int-1-risk subgroups. The LR-PSS may be useful in identifying patients with lower-risk disease who have poorer prognosis and require earlier treatment.

The prognostic value of the LR-PSS has been validated in several independent studies.^{66,194,211-213} In a retrospective analysis of data from patients with lower-risk MDS (IPSS low or int-1) in the multicenter Spanish registry (N = 2373), the LR-PSS was able to further stratify patients with lower-risk disease into three risk categories.¹⁹⁴ Within the IPSS low-risk group, median survival was 130.3 months for category 1 (low risk), 69.7 months for category 2 (intermediate risk), and 58.4 months for category 3 (high risk) using the LR-PSS-risk categories ($P < .001$); the corresponding median survival values within the IPSS int-1-risk group using the LR-PSS risk categories were 115.2 months, 51.3 months, and 24.1 months, respectively ($P < .001$). An important proportion of patients (30%) within the IPSS int-1-risk group were identified as having a poorer prognosis as indicated by their inclusion in the high-risk group (24.1 months).

Data from a cohort of patients with lower-risk MDS from two centers (N = 664) demonstrated a median survival according to the LR-PSS risk categories of 91.4 months for category 1, 35.6 months for category 2, and 22 months for category 3.²¹³ Using data from the same cohort of patients, median survival according to the IPSS-R-risk groups was 91.4 months for IPSS-R very good, 35.9 months for good, and 27.8 months for the combined intermediate-, high-, and very-high-risk groups. Both of these prognostic scoring systems were significantly predictive of survival outcomes. The predictive powers (based on Harrell's C statistics) of the LR-PSS and IPSS-R were 0.64 and 0.63, respectively.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Molecular Abnormalities in MDS

Several gene mutations have been identified among patients with MDS that may, in part, contribute to the clinical heterogeneity of the disease course, and thereby influence the prognosis of patients. Such gene mutations will be present in the majority of newly diagnosed patients, including most patients with normal cytogenetics. Several studies examining large numbers of MDS tumor samples have identified more than 40 recurrently mutated genes with >80% of patients harboring at least one mutation.^{66,214-216} The most frequently mutated genes were *TET2*, *SF3B1*, *ASXL1*, *DNMT3A*, *SRSF2*, *RUNX1*, *TP53*, *U2AF1*, *EZH2*, *ZRSR2*, *STAG2*, *CBL*, *NRAS*, *JAK2*, *SETBP1*, *IDH1*, *IDH2*, and *ETV6*, although no single mutated gene was found in more than one third of patients. Several of these gene mutations are associated with adverse clinical features such as complex karyotypes (*TP53*), excess bone marrow blast proportion (*RUNX1*, *NRAS*, and *TP53*), and severe thrombocytopenia (*RUNX1*, *NRAS*, and *TP53*). See the IPSS-M section above and *Prognostic Scoring Systems* in the algorithm for a discussion of mutational changes in MDS as noted in the IPSS-M.²⁰⁹

Despite associations with clinical features considered by prognostic scoring systems, mutations in several genes hold independent prognostic value. Mutations of *TP53*, *EZH2*, *ETV6*, *RUNX1*, and *ASXL1* have been shown to predict decreased OS in multivariable models adjusted for IPSS or IPSS-R risk groups in several studies of distinct cohorts.^{214,216} Within IPSS risk groups, a mutation in one or more of these genes identifies patients whose survival risk resembles that of patients in the next highest IPSS risk group (eg, the survival curve for patients with int-1-risk disease with an adverse gene mutation was similar to that of patients assigned to the int-2-risk group by the IPSS).²¹⁴ When applied to patients stratified by the IPSS-R, the presence of a mutation in one or more of these five genes was associated with shorter OS for patients in the low- and intermediate-risk groups.²¹⁶ Thus, the combined analysis of these gene mutations and

the IPSS or IPSS-R may improve upon the risk stratification provided by these prognostic models alone. Mutations of *ASXL1* have also been shown to carry independent adverse prognostic significance in CMML.^{217,218} Other mutated genes have been associated with decreased OS, including *DNMT3A*, *U2AF1*, *SRSF2*, *CBL*, *PRPF8*, *SETBP1*, and *KRAS*.^{214,216,219-223} Only mutations of *SF3B1* have been associated with a more favorable prognosis even after adjustment for the IPSS-R in several, but not all studies.^{216,224,225}

TET2 mutations have been shown to impact the response to HMAs.^{226,227} Patients with mutated *TET2* had an 82% response rate to AzaC compared to 45% of patients with wild-type *TET2* ($P = .007$). Response duration and OS were not statistically different.²²⁶ Another study identified 39 genes that were mutated in 213 patients with MDS treated with AzaC or decitabine.²²⁷ A higher response to HMAs in patients with the *TET2* mutation, albeit to a lesser degree, was seen (response rate, 55% vs. 44%; $P = .14$). This improved response was more pronounced when patients with *ASXL1* mutations and those with only low abundance *TET2* mutations were excluded (OR, 3.65; $P = .009$). Mutations in *TP53* and *PTPN11* correlated with shorter OS but did not affect drug response. However, the predictive capabilities of these mutations are modest. The status of these molecular markers in patients should not preclude the use of HMAs nor be used to influence the selection of HMAs.

Mutations of *TP53* are strongly associated with complex and monosomal karyotypes. However, approximately 50% of patients with a complex karyotype have no detectable *TP53* abnormality and have an OS that is comparable to that of patients with non-complex karyotypes. Therefore, *TP53* mutation status may be useful for refining the prognosis of these patients typically considered to have higher-risk disease.²¹⁴ Patients with del(5q), either as an isolated abnormality or often as part of a complex karyotype, have a higher rate of concomitant *TP53* mutations.^{228,229} These



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

mutations are associated with diminished response or relapse after treatment with lenalidomide.^{230,231} In these cases, *TP53* mutations may be secondary events and are often present in small subclones that can expand during treatment. More sensitive techniques may be required to identify the presence of subclonal, low-abundance *TP53* mutations prior to treatment.

Mutations identified in peripheral blood samples can accurately reflect mutations detected in the bone marrow of patients with MDS when more sensitive sequencing techniques are used to detect them.²³²

Comorbidity Indices

Patients with MDS predominantly comprise an older adult population, posing potential challenges in terms of treatment tolerability and outcomes due to the presence of comorbid conditions. Approximately 50% of patients with newly diagnosed MDS present with one or more comorbidities, with cardiac disease and diabetes among the most frequently observed conditions.²³³⁻²³⁷ Assessment of the presence and degree of comorbidities using tools such as the Charlson Comorbidity Index (CCI) or the Hematopoietic Cell Transplantation-Specific Comorbidity Index (HCT-CI) has demonstrated the significant prognostic influence of comorbidities on the survival outcome of patients with MDS.^{233,235-237} Some studies have shown that comorbidity (as measured by HCT-CI or Adult Comorbidity Evaluation-27 [ACE-27]) was a significant prognostic factor for survival, independent of IPSS.^{234,237} In these studies, comorbidity indices provided additional prognostic information for survival outcomes in patients with MDS categorized as IPSS intermediate or high risk, but not for patients considered to have low-risk disease.

Conversely, in another study, comorbidity (as measured by HCT-CI or CCI) was a significant predictor of OS and event-free survival in patients within the low-risk or int-1-risk groups, but not in the int-2-risk or high-risk

groups.²³⁵ Comorbidity has also been shown to provide additional risk stratification among WPSS risk categories (for very low-, low-, and intermediate-risk groups but not for high- or very-high-risk groups), prompting the development of a new MDS-specific comorbidities index that can be used in conjunction with WPSS for the assessment of prognosis.²³⁸ Improved risk stratification has also been demonstrated with the incorporation of the Myelodysplastic Syndromes Comorbidity Index with the IPSS-R.²⁰¹ At this time, the NCCN MDS Panel makes no specific recommendations with regard to the optimal comorbidity index to be used for patients with MDS. However, a thorough evaluation of the presence and extent of comorbid conditions remains an important aspect of treatment decision-making and management of MDS.

Therapeutic Options

The IPSS or IPSS-R risk categories are used in the initial planning of therapeutic options, because they provide a risk-based patient evaluation. In addition, factors such as patient age, performance status, and presence of comorbidities have a major influence on the patient's ability to tolerate certain intensive treatments and play a major role in selecting the optimal management strategy. The WPSS provides dynamic estimation of prognosis at any time during the course of MDS.

If the patient was only recently evaluated, determining the relative stability of the patient's blood counts over several months is important to assess whether the disease progresses, including incipient transformation to AML. In addition, this assessment permits determination of other possible etiologies for cytopenias. The patient's preference for a specific approach is also important in deciding treatment options. The therapeutic options for MDS include supportive care, low-intensity therapy, high-intensity therapy including allogeneic HCT, targeted agents, and participation in a clinical trial. In evaluating results of therapeutic trials, the Panel found it important for studies to use the standardized IWG response criteria.²³⁹⁻²⁴⁴



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

For the MDS therapeutic algorithm, all patients should receive relevant supportive care. Following that, the MDS Panel has proposed stratifying patients with clinically significant cytopenia(s) into two major risk groups: 1) patients with lower-risk MDS (ie, IPSS low, int-1; IPSS-R very low, low, intermediate; WPSS very low, low, intermediate); and 2) patients with higher-risk MDS (ie, IPSS int-2, high; IPSS-R intermediate, high, very high; WPSS high, very high). Patients with IPSS-R intermediate risk may be treated as lower risk if their score is ≤ 3.5 versus higher risk if their score is > 3.5 .²⁰² In addition, patients with intermediate-risk disease that does not respond to therapy for lower-risk disease would be eligible to receive therapy for higher-risk MDS.

Based on IWG response criteria, the major therapeutic aim for patients in the lower-risk group would be hematologic improvement, whereas for those in the higher-risk group, alteration of the natural history of disease is viewed as paramount. Cytogenetic response and quality-of-life (QOL) parameters are also important outcomes to assess. The algorithm outlines management of primary MDS only. Most patients with t-MDS have poorer prognoses than those with primary MDS, including a substantial proportion with poor-risk cytogenetics. This disease is generally managed as higher-risk disease.

Supportive Care

Currently, the standard of care for MDS management includes supportive care measures (see *Supportive Care* in the algorithm and the [NCCN Guidelines for Supportive Care](#)). This entails observation, clinical monitoring, psychosocial support, and QOL assessment. Prior to transplant, transplant patients should receive support.

Supportive care should include RBC transfusions for symptomatic anemia as needed (CMV-safe [CMV-negative or leukopheresed]) or platelet transfusions for bleeding events; however, platelet transfusions are

generally not used routinely in patients with thrombocytopenia in the absence of bleeding. CMV-safe blood products are recommended whenever possible for recipients who are CMV-negative. Both the number of transfusions as well as the number of packed RBCs per transfusion should be kept to a minimum in patients who are classified as non-cardiac and in patients anticipated to be heavily transfused. The NCCN Guidelines Panel is in agreement with the 2013 American Society of Hematology (ASH) Choosing Wisely initiative addressing hematologic tests and treatments.²⁴⁵ There was non-uniform consensus among the Panel members based on differing institutional policies regarding the necessity for routine irradiation of blood products used in patients with MDS; however, the Panel agreed that all directed-donor products and transfused products for patients who are potential transplant candidates should be irradiated. Additionally, CMV-safe (CMV-negative or leukopheresed) blood products are recommended whenever possible for recipients who are CMV-negative. Antibiotics are recommended for bacterial infections and prophylaxis may be considered when starting patients on therapy, consistent with local hospital guidelines. Aminocaproic acid or other antifibrinolytic agents may be considered for bleeding episodes refractory to platelet transfusions or for profound thrombocytopenia. Hematopoietic cytokine support should be considered for refractory symptomatic cytopenias.²⁴⁶ For example, recombinant human granulocyte colony-stimulating factor (G-CSF) treatment could be considered for patients with MDS with neutropenia with recurrent or resistant bacterial infections.

Post-transplantation, patients should receive antibiotic prophylaxis at least as long as they are on immunosuppressive therapy. Detailed recommendations are provided in the Guidelines generated by the American Society of Transplantation and Cellular Therapy²⁴⁷ and the [NCCN Guidelines for Hematopoietic Cell Transplantation](#).



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

Management of Thrombocytopenia

Severe thrombocytopenia is associated with an increased risk for bleeding events, and is currently managed with platelet transfusions. The mechanism of thrombocytopenia in patients with MDS may be attributed to decreased platelet production (possibly related to regulatory pathways involving the production and/or metabolism of endogenous thrombopoietin [TPO]) as well as increased destruction of bone marrow megakaryocytes or circulating platelets.^{248,249} Increased endogenous TPO levels have been reported among patients with MDS compared with healthy individuals.²⁴⁹ At the same time, TPO receptor sites per platelet were decreased among patients with MDS compared to healthy individuals. The RA subgroup (as defined by Bennett et al²⁵⁰) appeared to have the highest TPO levels compared with patients with MDS-EB or MDS-EB-T, while the number of TPO receptor sites remained similar across subtypes.²⁴⁹ Studies have reported that high endogenous TPO levels correlated with decreased platelet counts in patients with RA, but not in patients with MDS-EB or MDS-EB-T.^{249,251} This observation suggests that the regulatory pathway for endogenous TPO may be further disrupted in the latter group, potentially due to overexpression of TPO receptors in blasts that could lead to an inadequate TPO response.^{249,251}

Several studies are investigating the role of the TPO receptor agonist romiplostim in the treatment of thrombocytopenia in patients with lower-risk MDS.²⁵²⁻²⁵⁷ Phase I/II studies with romiplostim showed promising rates of platelet response (46%–65%) in patients with lower-risk MDS.^{253,255} Randomized placebo-controlled studies in patients treated for lower-risk MDS have reported beneficial effects of romiplostim in terms of decreased bleeding events, reduced need for platelet transfusions in patients receiving HMsAs,^{252,254} and decreased frequency of dose reductions or delays in patients receiving lenalidomide therapy.²⁵⁶ In a randomized study including patients with low- or int-1-risk MDS (n = 250), romiplostim was associated with increased platelet counts and decreased

overall bleeding events ($P = .026$ after 58 weeks of treatment compared to the placebo group).²⁵⁸ However, due to the early drug discontinuation, interpretation of these data is limited. Following up on previous studies,^{253,258} an open-label extension study evaluated the long-term safety and efficacy of romiplostim in 60 patients with lower-risk MDS and found that most patients achieved durable responses.²⁵⁹ A model to predict response to romiplostim indicated that lower-risk MDS, lower baseline TPO levels (<500 pg/mL), and limited platelet transfusion history had the greatest effect on subsequent platelet response to romiplostim.²⁵⁷

Eltrombopag is another TPO receptor agonist that has been shown to increase normal megakaryopoiesis in vitro in bone marrow cells isolated from patients with MDS.^{260,261} Ongoing phase I and II clinical trials are investigating the activity and safety of this agent for the treatment of thrombocytopenia in patients with lower-risk MDS. A phase II study enrolled patients with low-risk or IPSS int-1 risk MDS with severe thrombocytopenia who were randomized 2:1 to receive eltrombopag or placebo.²⁶² At the time of the interim analysis, in the intention-to-treat population, 47% of patients receiving eltrombopag demonstrated a platelet response, as opposed to 3% of patients in the placebo group ($P < .0001$; OR, 27.1 [95% CI, 3.5–211.9; $P = .0017$]). Forty-six percent of patients in the eltrombopag arm had grade 3–4 adverse events compared to 16% in the placebo group ($P = .0053$). Fewer bleeding events were reported in the eltrombopag arm compared to the placebo arm (14% vs. 42%, respectively; $P = .0025$). The results from another phase II trial determined that eltrombopag monotherapy in patients with lower-risk MDS with cytopenia, including anemia, thrombocytopenia, or neutropenia, led to a 44% rate of hematologic response at 16 to 20 weeks.²⁶³ A few patients acquired chromosomal abnormalities. A study by Fan et al²⁶⁴ found that 50% of patients with moderate aplastic anemia or unilineage cytopenias (platelet count $<30 \times 10^9/L$ or dependence on platelet transfusions or hemoglobin count $<8.5 \text{ g/dL}$ or dependence on



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

RBC transfusions) treated with eltrombopag achieved a clinically meaningful response at 16 to 20 weeks. Out of 34 patients, two patients acquired cytogenetic abnormalities.

A phase II trial evaluated eltrombopag monotherapy or eltrombopag in combination with HMAs in adults who have had >4 cycles of HMAs but who have disease that fails to respond to treatment or disease that continues to have ongoing cytopenias.^{265,266} Out of 28 evaluable patients, three of those who received the combination treatment showed platelet improvement and three had progressive disease. The median OS was 12 months. The phase II ASPIRE trial evaluated eltrombopag monotherapy for thrombocytopenia in adult patients with intermediate-2 or high-risk MDS and AML.²⁶⁷ Patients on eltrombopag monotherapy experienced significantly fewer clinically relevant thrombocytopenic events compared to those on placebo. However, there was no improvement in hematologic parameters or in platelet transfusion independence.

Concerns for potential proliferation of leukemic blasts in response to exogenous TPO have been raised in earlier in vitro studies, particularly for high-risk MDS.^{268,269} Results from ongoing clinical trials with TPO mimetics will help to elucidate the risks for leukemic transformations in patients with MDS. It should be noted that neither romiplostim nor eltrombopag is currently approved for use in patients with MDS.

Management of Iron Overload

RBC transfusions are a key component in the supportive care of patients with MDS. Although the specific therapies patients receive may alleviate RBC transfusion need, a substantial proportion of patients with MDS may not respond to these treatments and may develop iron overload and its consequences.²⁷⁰ Thus, effective treatment of transfusional siderosis in patients with MDS may be necessary.

Studies in patients requiring relatively large numbers of RBC transfusions (eg, thalassemia, MDS) have demonstrated the pathophysiology and adverse effects of chronic iron overload on hepatic, cardiac, and endocrine function. Increased non-transferrin-bound iron, generated when plasma iron exceeds transferrin-binding capacity, combines with oxygen to form hydroxyl and oxygen radicals. These toxic elements cause lipid peroxidation and cell membrane, protein, DNA, and organ damage.^{271,272}

Although limited, there is evidence suggesting that organ dysfunction can result from iron overload in patients with MDS.²⁷³⁻²⁷⁵ Retrospective data indicate that transfusional iron overload might be a contributor of increased mortality and morbidity in early-stage MDS.²⁷⁶ The WPSS has shown that the requirement for RBC transfusion is a negative prognostic factor for patients with MDS.²⁰³ A few studies have reported an improvement in OS for patients receiving iron chelation therapy compared to those who did not.²⁷⁷⁻²⁷⁹ However, prospective studies are required to substantiate the value of iron chelation in these patients.

A randomized prospective trial with 225 patients with lower-risk MDS (IPSS low or int-1) and serum ferritin levels >2247 pmol/L demonstrated the benefit of iron chelation therapy.²⁸⁰ Compared to patients in the placebo arm ($n = 76$), patients in the deferasirox arm ($n = 149$) had a higher median event-free survival (3.9 years [95% CI, 3.2–4.3 years] vs. 3.0 years [95% CI, 2.2–3.7 years]; hazard ratio [HR] = .64 [95% CI, 0.42–0.96]). The median OS was 5.2 years (95% CI, 3.9 years—not evaluable) and 4.1 years (3.0–4.9 years) for the deferasirox arm and the placebo arm respectively (HR = .83; 95% CI, .54–1.28). Per the IWG 2006 response criteria, the hematologic improvement in erythroid response was achieved in 39.6% (95% CI, 31.4%–47.8%) of patients treated with deferasirox compared to 27.6% (95% CI, 16.9%–38.3%) of patients treated with placebo.



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

For patients with chronic RBC transfusion need, serum ferritin levels and associated organ dysfunction (heart, liver, and pancreas) should be monitored. The NCCN Panel Members recommend monitoring serum ferritin levels and number of RBC transfusions received as a practical means to determine iron stores and assess iron overload. Monitoring serum ferritin may be useful, aiming to decrease ferritin levels to <1000 mcg/L. Beyond this level, serum ferritin can negatively impact the OS of patients with MDS.²⁸¹ It is recognized that such measurements, although useful, are less precise than Superconducting Quantum Interference Device (SQUID), or T2* MRI, to provide a specific measurement of hepatic iron content.^{282,283}

Reversal of some of the consequences of iron overload in MDS and other iron overload states by iron chelation therapy has been shown in patients in whom the most effective chelation occurred.^{241,272} This included transfusion independence (TI) in a subset of the small group of patients with MDS who had undergone effective deferoxamine chelation for 1 to 4 years.²⁸⁴ In addition, improvement in cardiac iron content was demonstrated in these patients after chelation.²⁸⁵ Such findings have major implications for altering the morbidity of patients with MDS, particularly those with pre-existing cardiac or hepatic dysfunction.

The availability of iron chelators, such as deferoxamine²⁸⁶ and deferasirox,²⁸⁷⁻²⁸⁹ provide potentially useful drugs to more readily treat iron overload. Deferoxamine (given as intramuscular or subcutaneous [SC] injections) is indicated for the treatment of chronic iron overload due to transfusion-dependent (TD) anemias.²⁸⁶ Deferasirox (given orally) is indicated for the treatment of chronic iron overload due to blood transfusions.²⁸⁷ Deferasirox has been evaluated in multiple phase II clinical trials in patients with TD-MDS.²⁹⁰⁻²⁹² A randomized phase II study evaluated the outcomes of deferasirox compared to placebo in patients with low- to intermediate-1-risk MDS.²⁸⁰ The results demonstrated that

deferasirox prolonged the median event-free survival by approximately 1 year.²⁸⁰ The prescribing information for deferasirox contains a black-box warning pertaining to the increased risks for renal or hepatic impairment/failure and GI bleeding in certain patient populations, including patients with high-risk MDS. Deferasirox is contraindicated in patients with high-risk MDS.

A third oral chelating agent, deferiprone, was approved (October 2011) in the United States for the treatment of patients with transfusional iron overload due to thalassemia when current chelation therapy is inadequate.²⁹³ The U.S. Food and Drug Administration (FDA) approval was based on results from a retrospective analysis of data pooled from previous safety and efficacy studies of deferiprone in patients with transfusion-related iron overload refractory to existing chelation therapy. The prescribing information for deferiprone contains a black-box warning pertaining to risks for agranulocytosis, which can lead to serious infections and death.²⁹³ Controversy remains regarding the use of this agent. The NCCN Task Force report, *Transfusion and Iron Overload in Patients with Myelodysplastic Syndromes*, provides detailed evidence regarding iron chelation in patients with MDS.²⁹⁴

The NCCN Guidelines Panel recommends consideration of once-daily deferoxamine SC or deferasirox/ICL670 orally to decrease iron overload in patients who have received >20 to 30 RBC transfusions, particularly for those who have lower-risk MDS or who are potential transplant candidates (with Low/int-1 MDS). For patients with serum ferritin levels >2500 ng/mL, aim to decrease ferritin levels to <1000 ng/mL.

As mentioned above, a black-box warning was added to the prescribing information for deferasirox.²⁸⁷ Following post-marketing use of deferasirox, there were case reports of acute renal failure, or hepatic failure, some of which were fatal. Most of the fatalities reported were in patients with multiple comorbidities and in advanced stages of their hematologic



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

disorders. Additionally, there were post-marketing reports of cytopenias, including agranulocytosis, neutropenia, and thrombocytopenia, and GI bleeding in patients treated with deferasirox; some cases resulted in death. The relationship of these episodes to treatment with deferasirox has not yet been established. However, it is recommended that patients on deferasirox therapy be closely monitored. Monitoring should include measurement of serum creatinine and/or creatinine clearance and liver function tests prior to initiation of therapy and regularly thereafter. Deferasirox and deferoxamine should be avoided in patients with creatinine clearance <40 mL/min.²⁸⁷ A recent phase IV study with 61 patients with MDS or AA determined that the adverse events noted within a 3-year period were largely mild or moderate.²⁹⁵

Treatment of Related Anemia

Erythropoiesis-stimulating agents (ESAs) such as epoetin alfa or the longer-acting darbepoetin, with or without G-CSF, have been evaluated in the treatment of symptomatic anemia in patients with MDS. Studies predominantly in patients with lower-risk MDS have demonstrated erythroid response rates of 40% and 60% (combined major and minor responses using IWG response criteria) in the initial trials.^{296,297} Clinical trial results in patients with MDS have suggested that the overall response rates to darbepoetin are similar to or possibly higher than epoetin.^{296–299} The improved response rates may in part be due to the dosage used (150–300 mcg SC per week) or to the fact that better-risk patients were enrolled in studies of darbepoetin compared to epoetin. Features predictive of response have included relatively low basal sEPO levels, low percentage of marrow blasts, and few prior RBC transfusions.

In a phase II study of patients with MDS (RA, MDS-RS, and MDS-EB; N = 50), Epo combined with G-CSF (n = 47 evaluable) resulted in hematologic responses in 38% of patients (complete response [CR], 21%).³⁰⁰ Epo and G-CSF appeared to have synergistic activity. Lower

sEPO levels (<500 mU/mL) and a lower pretreatment RBC transfusion requirement (<2 units per month) were associated with a higher response rate; response rates were not significantly different across IPSS risk groups. Median survival, including in patients from a prior study, was 26 months (N = 71). Among patients with low-risk IPSS, median survival had not been reached at 5 years; the 5-year survival rate was 68%. Median survival times among the int-1– and int-2–risk groups were 27 months and 14 months, respectively. AML progression occurred in 28% of patients overall during the observation period. The frequency of AML progression in the low-, int-1–, int-2–, and high-risk groups were 12%, 21%, 45%, and 100%, respectively. Among patients with responding disease who received maintenance treatment with Epo and G-CSF, the median duration of response was 24 months.

A subsequent analysis of combined data from three phase II Nordic trials (n = 121) on the long-term outcomes with Epo plus G-CSF (given for 12–18 weeks and followed by maintenance in responders) in patients with MDS reported a hematologic response rate of 39% with a median duration of response of 23 months.³⁰¹ Long-term outcomes were compared with outcomes from untreated patients (n = 237) as controls. Based on multivariate Cox regression analysis, treatment with Epo plus G-CSF was associated with a significantly improved survival outcome (HR, 0.61; 95% CI, 0.44–0.83; P = .002). An exploratory analysis revealed that the association between treatment and survival was significant only for the IPSS low-risk group and was further restricted to patients requiring fewer than 2 units of RBC transfusions per month. No significant association was found between the treatment and frequency of AML progression.

Similar findings were reported in a study from the French myelodysplasia group, which analyzed outcomes with ESAs (epoetin or darbepoetin), with or without G-CSF, in patients with MDS with anemia (N = 403).³⁰² Based on the IWG 2000 criteria, the hematologic response rate was 62% with a



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

median duration of 20 months; the corresponding results from the IWG 2006 criteria were 50% and 24 months, respectively. IPSS low- or int-1-risk was associated with significantly higher response rates and longer response durations. In a comparison of outcomes (in the low- or int-1-risk subset with anemia) between treated patients ($n = 284$) and a historical cohort of untreated patients ($n = 225$), multivariate analysis showed a significant association between treatment with ESAs and survival outcomes. The frequency of AML progression was similar between the cohorts. In a phase II study that evaluated darbepoetin (given every 2 weeks for 12 weeks), with or without G-CSF (added at 12 weeks in non-responders), patients in the lower-risk IPSS group with anemia (and sEPO levels <500 mU/mL) had hematologic response rates of 48% at 12 weeks and 56% at 24 weeks.³⁰³ Median duration of response was not reached at the median follow-up of 52 months. The 3-year cumulative incidence of AML progression was 14.5%, and the 3-year survival rate was 70%. This study also showed improvements in QOL parameters among patients with responding disease.³⁰³

Collectively, these studies suggest that ESAs may provide clinical benefit to patients in the lower-risk group with symptomatic anemia. Limited data are available on the effectiveness of ESAs in the treatment of anemia in patients with lower-risk MDS with del(5q). Epo has been shown to promote the growth of cytogenetically normal cells isolated from patients with del(5q), while having minimal proliferative effects on MDS progenitor cells from these patients *in vitro*.³⁰⁴ Retrospective studies from the French group reported hematologic response rates between 46% and 64%, with a median response duration of 11 months (mean duration, 13–14 months) among patients with del(5q) treated with ESAs, with or without G-CSF.^{302,305} Duration of response in these patients was significantly decreased compared with patients without del(5q) (mean duration, 25–27 months). Based on multivariate analysis, del(5q) was a significant

predictor of a shorter response duration with treatment (see *Prognostic Category Very Low, Low, Intermediate-1 Treatment* in the algorithm).³⁰²

In March 2007 and 2008, the FDA announced alerts and strengthened safety warnings for the use of ESAs based on observed increased mortality and possible tumor promotion and thromboembolic events in non-MDS patients receiving ESAs when dosing to achieve a targeted hemoglobin level >12 g/dL. Specifically, the study patients had chronic kidney failure; were receiving radiation therapy for various malignancies, including head and neck cancer, advanced breast cancer, lymphoid cancer, or non-small cell lung cancer; were patients with cancer not receiving chemotherapy; or were patients undergoing orthopedic surgery. However, ESAs have been used safely in large numbers of adult patients with MDS and have become important for symptomatic improvement of anemia caused by this disease, often with a decrease in RBC transfusion requirements. Studies assessing the long-term use of Epo with or without G-CSF in patients with MDS have shown no negative impact of such treatment on survival or AML evolution when compared to either randomized controls³⁰⁶ or historical controls.^{301,302}

Jadersten et al³⁰¹ reported improved survival in patients with low-risk MDS with low transfusion need following treatment with these agents. In another study, improved survival and decreased AML progression of patients with IPSS low or int-1 following Epo treatment, with or without G-CSF, compared to the historical control IMRAW database patients were reported.³⁰² Thus, these data do not indicate a negative impact of these drugs in the treatment of MDS. Given these data, the NCCN Panel recommends the use of ESAs in the management of symptomatic anemia in patients with MDS, with a target hemoglobin range of 10 to 12 g/dL but not exceeding 12 g/dL.

The phase III randomized COMMANDS trial evaluated the use of luspatercept in patients with no del(5q) with very-low risk, low-risk, or



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

intermediate-risk IPSS-R MDS (73% of whom had ring sideroblasts), with no prior ESAS treatment and who needed RBC transfusions.³⁰⁷ Data from an interim efficacy analysis revealed that 59% of patients receiving luspatercept achieved the primary endpoint of RBC transfusion independence for 12 weeks or longer and a mean hemoglobin increase of ≥ 1.5 g/dL, compared to 31% of patients receiving epoetin alfa ($P < .0001$). In patients with ring sideroblasts, responses were 65% with luspatercept versus 26% with epoetin alfa but in those with ring sideroblast-negative disease, responses were similar, 41% with luspatercept versus 46% for epoetin alfa. The median duration of responses was 127 weeks for luspatercept versus 77 weeks for epoetin alfa. Occurring in $\geq 3\%$ of patients, fatigue, asthenia, nausea, dyspnea, hypertension, and headache were the most frequent suspected treatment-related adverse events in patients receiving luspatercept. No treatment-related adverse events occurred in $\geq 3\%$ of patients receiving epoetin alfa.

Clinical trials with other experimental agents that are reportedly capable of increasing hemoglobin levels should be explored in patients with disease that is not responding to standard therapy. These drugs should be used in the context of therapeutic approaches for the underlying prognostic risk group.

In March 2007, the Centers for Medicare & Medicaid Services (CMS) generated a National Coverage Determination (NCD) on the use of ESAs in non-renal disease applications. Following a public comment period, it was determined that the scope of the NCD should be revised to include cancer and related neoplastic conditions. The narrowed scope of the NCD excludes MDS as it is defined in the report as a premalignant condition and not an oncologic disease.³⁰⁸ Thus, local Medicare contractors may continue to make reasonable and necessary determinations on the use of ESAs that are not determined by the NCD.

Treatment of MDS-Related ESA-Refractory Anemia

Anemia associated with lower-risk MDS generally becomes resistant to available treatment, leading to a dependence on RBC transfusions, iron overload, and decreased QOL and survival.^{189,309-311} In November 2019, the FDA approved the use of luspatercept for the treatment of anemia in adult patients with beta thalassemia who require regular RBC transfusions. Luspatercept is a recombinant fusion protein made up of a modified extracellular domain of the human activin receptor type IIB linked to the human IgG1 Fc domain that binds transforming growth factor beta (TGF β) ligands to reduce SMAD2 and SMAD3 signaling, which enables erythroid maturation.³¹² In April 2020, based on encouraging phase III data,³¹¹ the FDA approved luspatercept for the treatment of anemia in patients with lower-risk MDS with ring sideroblasts that failed treatment with ESAs. In the phase III MEDALIST trial, patients with very-low-risk, low-risk, or intermediate-risk MDS with ring sideroblasts who had been receiving regular RBC transfusions were either treated with luspatercept ($n = 153$) or given placebo ($n = 76$).³¹¹ In this trial, eligible patients had MDS with ring sideroblasts according to the WHO criteria (ie, either $\geq 15\%$ ring sideroblasts or $\geq 5\%$ ring sideroblasts if an SF3B1 mutation was present, and with $<5\%$ bone marrow blasts); and had disease that was refractory to or was unlikely to respond to ESAs. During weeks 1 through 24 of treatment, 38% of patients in the luspatercept group, compared to 13% of those in the placebo group, met the study primary endpoint of transfusion independence for 8 weeks or longer ($P < .001$). The median duration of the longest single continuous period of response to luspatercept was 30.6 weeks. The most common adverse events associated with luspatercept included fatigue, diarrhea, asthenia, nausea, and dizziness, which decreased over time. Additionally, 81.0% of patients in the luspatercept group met the secondary endpoint of a mean absolute increase in neutrophil count of $\geq 0.5 \times 10^9/L$ from baseline compared to 51.3% of patients in the placebo group. 70.6% and 42.1% of patients in the luspatercept and placebo groups, respectively, met the secondary



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

endpoint of a mean absolute increase in platelet count of $\geq 30 \times 10^9/L$.³¹³ In the overall population, 4.6% and 7.9% of patients in the luspatercept and placebo groups, respectively, had treatment-emergent grade 3 or 4 neutropenia.

In a phase II multicenter, open-label, dose-finding study (PACE-MDS), patients with low- or intermediate-1 risk MDS or non-proliferative CMML who had anemia with or without RBC transfusion support were treated with luspatercept ($n = 58$).³¹⁴ Of importance, 78% of the treated patients had $\geq 15\%$ ring sideroblasts, which was a positive predictor of response. Some patients were enrolled in a dose-escalation cohort ($n = 27$) receiving luspatercept once every 21 days at doses ranging from 0.125 to 1.75 mg/kg over a maximum of 12 weeks. Other patients enrolled in the dose-expansion cohort ($n = 31$) received luspatercept doses ranging from 1.0 to 1.75 mg/kg, and patients could be treated for up to 5 years.³¹⁴ Thirty-two of 51 patients (63%) who received higher doses of luspatercept (0.75–1.75 mg/kg) achieved hematologic improvement-erythroid, defined as: hemoglobin concentration increase of ≥ 1.5 g/dL from baseline for at least 14 days in patients with low transfusion burden, and a reduction in RBC transfusion of ≥ 4 RBC units or $\geq 50\%$ reduction in RBC units over 8 weeks versus pre-treatment transfusion burden in patients with high transfusion burden.³¹⁴

Long-term efficacy and safety data of the PACE-MDS study support the use of luspatercept.³¹⁵ Of the 108 patients who received treatment with luspatercept, 44 patients had non-ring sideroblastic disease and 48 had received prior treatment with ESAs. The hematologic improvement in erythroid response was 54% in the overall group and 36% in patients with non-ring sideroblastic MDS. Among 73 evaluable patients, 44% of the overall group achieved RBC-TI ≥ 8 weeks, compared to 35% of the subgroup with non-ring sideroblastic MDS. The most common

treatment-emergent adverse occurrences were headache, bone pain and hypertension in patients with non-ring sideroblastic MDS.

In a phase II trial comprising 57 patients with lower-risk MDS that had relapsed or was refractory to ESAs and who were RBC transfusion dependent, treatment with imetelstat, a telomerase inhibitor, resulted in a 37% and 23% RBC TI rates, at 8 and 24 weeks respectively.³¹⁶ At the same time points, RBC TI rates of 42% and 29% respectively were observed in a subgroup of 38 patients without del(5q) and who were not previously treated with an HMA or lenalidomide. The median duration for TI was 65 weeks for the overall group compared to 86 weeks in the subgroup. Hematologic improvement, in terms of erythroid response per the IWG 2006 response criteria, was achieved in 65% of patients in the overall group and 68% of patients in the subgroup. Overall, the most common grade ≥ 3 hematologic adverse events were neutropenia (60%), thrombocytopenia (54%), and anemia (19%). At 5%, the most common grade ≥ 3 nonhematologic adverse events were back pain, increased alanine aminotransferase, increased aspartate aminotransferase, and bronchitis.

In the phase III IMerge study, patients with IPSS low or intermediate-1 risk MDS with disease that relapsed or that was refractory to ESAs or who were ineligible (with sEPO >500 mU/mL) for ESAs were randomized 2:1 to receive treatment with imetelstat or placebo.³¹⁷ A higher percentage of patients treated with imetelstat achieved the primary endpoint of RBC-TI for at least 8 weeks (40% vs. 15% in the placebo arm; $P = .0008$) and the secondary endpoint of RBC-TI for at least 24 weeks (28% vs. 3% in the placebo arm; $P = .0001$). Out of those who achieved the primary endpoint, the median RBC-TI duration was 51.6 weeks with imetelstat and 13.3 weeks with placebo. Hematologic improvement-erythroid was observed in 64% of patients in the imetelstat arm (vs. 52% in the placebo arm) when assessed by the IWG 2006 response criteria. When assessed by the IWG



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

2018 criteria, hematologic improvement-erythroid was 42% in the imetelstat arm and 13% in the placebo arm. The results of a subgroup analysis showed that among patients with sEPO >500 mU/mL, 26.9% (vs. 9.1% for placebo; $P = .107$) and 15.4% (vs. 0.0% for placebo; $P = .050$) achieved TI with imetelstat at 8 weeks and 24 weeks, respectively. Ninety-one percent of patients treated with imetelstat experienced a grade 3–4 treatment emergent adverse event, compared to 47% of patients receiving placebo, with neutropenia (68% vs. 3% in the placebo arm) and thrombocytopenia (62% vs. 8% in the placebo arm) being reported as the most frequent events in those patients.

Low-Intensity Therapy

Low-intensity therapy includes the use of low-intensity chemotherapy or biologic response modifiers. Although this type of treatment is mainly provided in the outpatient setting, supportive care or occasional hospitalization (eg, for treatment of infections) may be needed.

Hypomethylating Agents

The DNA methyltransferase inhibitor (DMTI) HMs AzaC and decitabine (5-aza-2'-deoxycytidine) have been shown in randomized phase III trials to decrease the risk of leukemic transformation and, in a portion of patients, to improve survival.^{318–321} In a phase III trial that compared AzaC with supportive care in patients from all IPSS risk groups ($N = 191$; previously untreated in 83%), hematologic responses occurred in 60% of patients in the AzaC arm (7% CR, 16% partial response [PR], and 37% hematologic improvement) compared with a 5% hematologic improvement (and no responses) in patients receiving supportive care.³²¹ The median time to AML progression or death was significantly prolonged in the AzaC arm compared with patients receiving supportive care (21 vs. 13 months; $P = .007$). Further improvement was seen in patients who received AzaC earlier in the course of disease, suggesting that the drug prolonged the duration of stable disease. Subsequently, Silverman and colleagues³²²

provided a summary of three AzaC studies in a total of 306 patients with high-risk MDS.³²² In this analysis, which included patients receiving either SC or intravenous (IV) delivery of the drug, complete remissions were seen in 10% to 17% of patients treated with AzaC and partial remissions were rare; hematologic improvement was seen in 23% to 36% of these patients. Ninety percent of the responses occurred prior to cycle 6 with a median number of cycles to first response of 3.³²² The authors concluded that AzaC provided important clinical benefits for patients with high-risk MDS. Results from a phase III randomized trial in patients ($N = 358$) with higher-risk MDS (IPSS int-1, 5%; int-2, 41%; high risk, 47%) demonstrated that AzaC was superior to conventional care (ie, standard chemotherapy or supportive care) regarding OS.³¹⁸ AzaC was associated with a significantly longer median survival compared with conventional care (24.5 vs. 15 months; HR, 0.58; 95% CI, 0.43–0.77; $P = .0001$), thus providing support for the use of this agent in patients with higher-risk disease.

AzaC therapy is a recommended option for progressive MDS or relatively high-risk disease. This drug has been approved by the FDA for the treatment of patients with MDS and is generally administered at a dose of 75 mg/m²/day SC for 7 days every 28 days for at least six courses. Treatment courses may need to be extended further or may be used as a bridging therapy to more definitive therapy (eg, patients whose marrow blast counts require lowering prior to HCT). Although the optimal duration of therapy with AzaC has not been defined, some data suggest that continuation of AzaC beyond first response may improve remission quality. In a secondary analysis of the phase III randomized AZA-001 trial, continued AzaC therapy resulted in further improvement in response category in 48% of all responders.³²³ Although most patients with responding disease achieved a first response by 6 cycles of therapy, up to 12 cycles were required for the majority of responders to attain a best response.³²³ In this study, the median number of cycles from first response to best response was 3 to 3.5 cycles, and patients with responding



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

disease received a median of 8 additional cycles (range, 0–27 cycles) beyond first response.³²³

An alternative 5-day schedule of AzaC has been evaluated, both as an SC regimen (including the 5-2-2 schedule: 75 mg/m²/day SC for 5 days followed by 2 days of no treatment, then 75 mg/m²/day for 2 days, every 28 days; and the 5-day schedule: 75 mg/m²/day SC for 5 days every 28 days)³²⁴ and as an IV regimen (75 mg/m²/day IV for 5 days every 28 days).³²⁵ Although response rates with the 5-day regimens appeared similar to the approved 7-day dosing schedule,^{324,325} survival benefit with AzaC has only been demonstrated using the 7-day schedule.

Decitabine, given IV and administered with a regimen that required hospitalization of patients, has also shown encouraging results for the therapy of patients with higher-risk MDS. As the treatment regimen was generally associated with low-intensity-type toxicities, it is also considered to be a “low-intensity therapy.” In earlier phase II studies, approximately 30% of patients experienced cytogenetic conversion,³²⁶ with an overall response rate of 49%, and a 64% response rate was seen in patients with a high-risk IPSS score³²⁷; results were similar to those seen in AzaC studies.^{319,328}

A phase III randomized trial of decitabine (15 mg/m² IV infusion over 3 hours every 8 hours [ie, 45 mg/m²/day] on 3 consecutive days every 6 weeks for up to 10 cycles) compared with supportive care in adult patients (N = 170) with primary and secondary MDS (IPSS int-1, 30.5%; int-2, 43.5%; high risk, 26%) indicated higher response rates, remission durations, times to AML progression, and survival benefits in the int-2 and high-risk groups.³¹⁹ Overall response rate (CR + PR) with decitabine was 17% (median duration, 10 months), with an additional 13% of patients showing hematologic improvement. The probability of progression to AML or death was 1.68-fold greater for patients receiving supportive care than for patients receiving decitabine. Based on this study and three supportive

phase II trials,³²⁹ the drug has also been approved by the FDA for treating patients with MDS.

In another phase III randomized trial with this regimen, decitabine was compared with best supportive care (BSC) in patients ≥60 years of age (N = 233; median age, 70 years; range, 60–90 years) with higher-risk MDS (IPSS int-1, 7%; int-2, 55%; high risk, 38%) not eligible for intensive therapy.³²⁰ Median PFS was significantly improved in patients receiving decitabine compared with supportive care (6.6 vs. 3 months; HR, 0.68; 95% CI, 0.52–0.88; *P* = .004), and the risk of AML progression at 1 year was reduced with decitabine (22% vs. 33%; *P* = .036). However, no significant differences were observed between decitabine and supportive care for the primary endpoint of OS (10 vs. 8.5 months, respectively) or for median AML-free survival (8.8 vs. 6.1 months, respectively).³²⁰ In the decitabine arm, a CR and PR were observed in 13% and 6% of patients, respectively, with hematologic improvement in an additional 15%; in the supportive care arm, hematologic improvement was seen in 2% of patients (with no hematologic responses). Decitabine was associated with significant improvements in patient-reported QOL measures (as assessed by the European Organization for Research and Treatment of Cancer [EORTC] QOL Questionnaire C30) for the dimensions of fatigue and physical functioning.³²⁰

In 2007, Kantarjian and colleagues³³⁰ provided an update to their study of 115 patients with higher-risk MDS using alternative and lower-dose decitabine treatment regimens.³³⁰ Patients received one of three different schedules of decitabine, including both SC and IV administration with a mean of seven courses of therapy. Responses were improved with the longer duration of therapy. Overall, 80 patients (70%) responded with 40 patients achieving a CR and 40 achieving a PR. The median remission duration was 20 months with a median survival time of 22 months. The three different schedules of decitabine were compared in another



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

randomized study of 95 patients with MDS or CMML, receiving 20 mg/m²/day IV for 5 days; 20 mg/m²/day SC for 5 days; or 10 mg/m²/day IV for 10 days.³³¹ The 5-day IV schedule was considered the optimal schedule. The CR rate in this arm was 39%, compared with 21% in the 5-day SC arm and 24% in the 10-day IV arm ($P < .05$). Alternate dosing regimens using lower doses of decitabine administered in an outpatient setting are currently being evaluated.

A phase I dose-escalation study evaluated the combination of decitabine with cedazuridine in 44 patients with intermediate to high-risk MDS or CMML.³³² The clinical responses were comparable to those obtained with a 5-day treatment with IV decitabine. These results were confirmed in a phase II study documenting bioequivalence for this combination in patients with IPSS int-1 and above with 60% of patients achieving a clinical response and 21% of patients having a complete response.³³³ Results from the phase III ASCERTAIN randomized trial with a crossover design showed that the combination treatment had an equivalent decitabine exposure to IV decitabine.³³⁴ A clinical response was obtained in 70% of evaluable patients. Occurring in 61%, 57%, and 50% of patients, respectively, thrombocytopenia, neutropenia, and anemia were the most common ≥ 3 adverse events.

Several retrospective studies have evaluated the role of cytoreductive therapy with HMAs prior to allogeneic HCT (with both myeloablative and reduced-intensity conditioning [RIC] regimens).³³⁵⁻³³⁸ These studies suggest that HMAs may provide a feasible alternative to induction chemotherapy regimens prior to transplant, and may serve as a beneficial bridge to allogeneic HCT. The VidazaAllo study, which enrolled patients with higher-risk MDS aged 55 to 70 years, reported a higher event-free survival rate in patients who underwent transplant following a reduced-intensity conditioning regimen after pretreatment with AzaC, compared to those who received continuous AzaC therapy.³³⁹ One meta-analysis found

that the use of HMAs before HCT did not improve OS compared to chemotherapy, except in older patients.³⁴⁰ However, these agents should not be used in lieu of early transplantation or to delay transplantation until loss of response or disease progression.³⁴¹

AzaC and decitabine are considered to be therapeutically similar, although the improved survival of patients with higher-risk MDS treated with AzaC compared to control in a phase III trial, as indicated above, supports the preferred use of Azac as a first-line treatment option for patients with high-risk MDS who are not transplant candidates until more trial data are available. A lack of CR, PR or hematologic improvement, or frank progression to AML (in particular with loss of control [proliferation] of peripheral counts or excess toxicity that precludes continuation of therapy) may be indicative of disease that fails to respond to HMAs. The minimum number of courses prior to discontinuing treatment should be four courses for decitabine or six courses for AzaC. As discussed earlier, the optimal duration of therapy with HMAs has not been well-defined and no consensus exists. The NCCN Guidelines Panel generally feels that treatment should be continued if there is ongoing response and if there are no toxicities. Modifications should be made to the dosing frequency for individual patients in the event of toxicity.

As data have predominantly indicated altered natural history and decreased evolution to AML in patients who respond to DMTI HMAs, the major candidates for these drugs are 1) patients with IPSS int-2- or high-risk disease; or 2) IPSS-R intermediate-, high-, or very-high-risk disease with any of the following criteria:

- Patients who are not candidates for high-intensity therapy;
- Patients who are potential candidates for allogeneic HCT but for whom delay in receipt of that procedure is anticipated (eg, due to need to further reduce the blast count, improve patient performance status, or



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

identify a donor). In these circumstances, the drugs may be used as a bridging therapy for that procedure; or

- Patients with disease that is not expected to respond to (or with disease relapse after) ESAs or IST.

Biologic Response Modifiers and Immunosuppressive Therapy

The currently available non-chemotherapy, low-intensity agents (biologic response modifiers) include: ATG, cyclosporine, and lenalidomide, all of which have shown some efficacy in phase II and phase III trials.^{4,342-347}

Use of IST with ATG, with or without cyclosporine,^{345,347} has been shown in several studies to be most efficacious in patients with MDS with HLA-DR15 histocompatibility type, marrow hypoplasia, normal cytogenetics, low-risk disease, and evidence of a PNH clone.^{160,348} Researchers from the National Institutes of Health (NIH) have updated their analysis of 129 patients treated with IST with equine ATG alone, cyclosporine alone, or in combination.¹⁶² This study demonstrated markedly improved response rates in the subgroup of patients aged ≤60 years with IPSS int-1 risk or patients with high response probability characteristics as indicated by their prior criteria (ie, age, number of transfusions, possibly HLA-DR15 status).¹⁶²

Although equine ATG has been found to be more effective than rabbit ATG for treating AA,³⁴⁹ only limited data within the setting of MDS are available regarding the comparative effectiveness of the two ATG formulations. In a relatively small phase II study in patients with MDS (N = 35; primarily RA subtype), both equine and rabbit ATG were shown to be feasible and active.³⁵⁰ Some institutions have used tacrolimus in place of cyclosporine A based on the limited data that showed similar efficacy with lower incidence of adverse events in children with AA.^{351,352}

A phase I-II trial examined the combination of IST with eltrombopag in patients with aplastic anemia (not MDS).³⁵³ Three cohorts were used that differed by the schedule for the start of treatment and the duration of treatment. The most common grade 3 or above adverse event attributed to eltrombopag was an abnormality in a liver test (18%), specifically transaminase elevation and/or hyperbilirubinemia. The complete hematologic response and overall response rate (ORR) for the combined cohorts at 6 months, when compared to a historical cohort of 102 patients who were treated with IST, were 39% (95% CI, 29%–49%) versus 10% and 87% (95% CI, 80%–94%) versus 66%, respectively. The rate of clonal evolution was not increased in patients who received eltrombopag compared to a historical cohort at the 2-year time point. A phase II trial with patients with aplastic anemia reported an ORR of 76% in patients receiving the combination treatment compared to 71% in patients treated with IST only.³⁵⁴ The complete remission rate, median time to response, and the survival rate at 2 years were similar in both groups. One study showed that STAT3-mutant cytotoxic T-lymphocyte clones are present in a small proportion (5%) of patients with MDS (including those lacking LGLs), which is associated with HLA-DR15 positivity, marrow hypocellularity, and neutropenia.¹⁶¹ Despite lack of a survival difference in the STAT3-mutated versus patients with non-mutated MDS treated with IST in this small cohort, these findings suggest that STAT3-mutant cytotoxic T-lymphocyte clones may facilitate persistently dysregulated autoimmune activation akin to that present in other patients with MDS responsive to IST.¹⁶¹

Lenalidomide (a thalidomide analog) is an immunomodulating agent with activity in patients with lower-risk MDS.^{31,355} Beneficial results have been particularly evident for patients with the del(5q) chromosomal abnormality.^{31,355,356} A multicenter phase II trial of lenalidomide (10 mg/day for 21 days every 4 weeks or 10 mg daily) in patients with anemic RBC-TD MDS with del(5q), with or without additional cytogenetic abnormalities



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

($N = 148$), demonstrated that the hematologic response to lenalidomide was rapid (median time to response, 4.6 weeks; range, 1–49 weeks) and sustained.³¹ RBC-TI (assessed at 24 weeks) occurred in 67% of patients; among patients with IPSS low/int-1 risk ($n = 120$), 69% achieved TI.³¹ Cytogenetic responses were achieved in 62 of 85 evaluable patients (73%); 45% had a complete cytogenetic response. The most common grade 3 or 4 adverse events included myelosuppression (neutropenia, 55%; thrombocytopenia, 44%), which often required treatment interruption or dose reduction. Thus, careful monitoring of blood counts during the treatment period is mandatory when using this agent, particularly in patients with renal dysfunction (due to the drug's renal route of excretion). Lenalidomide has been approved by the FDA for the treatment of TD anemia in patients with IPSS low/int-1-risk MDS with del(5q) with or without additional cytogenetic abnormalities.

A phase III randomized controlled trial compared the activity of lenalidomide (5 mg/day for 28 days or 10 mg/day for 21 days every 28 days) versus placebo in patients with RBC-TD ($N = 205$) lower-risk MDS (IPSS low- and int-1 risks) and del(5q).³⁵⁷ The primary endpoint of RBC-TI ≥ 26 weeks was achieved in a significantly greater proportion of patients treated with lenalidomide (5 or 10 mg) versus placebo (37% vs. 57% vs. 2%, respectively; $P \leq .0001$ for both lenalidomide groups vs. placebo). Among patients achieving RBC-TI with lenalidomide, onset of erythroid response was rapid, with a median time of 4.2 weeks and 4.3 weeks in the 5-mg and 10-mg lenalidomide groups, respectively.³⁵⁷ Cytogenetic response rates were significantly higher for the lenalidomide 5-mg (23%; $P = .0299$) and 10-mg (57%; $P < .0001$) groups compared with placebo (0%); CR rates were observed in 12% and 35% of patients in the lenalidomide 5-mg and 10-mg arms, respectively. The estimated 2-year cumulative risk to AML progression was 17% (95% CI, 8.7–33.3), 12.6% (95% CI, 5.4–27.7), and 16.7% (95% CI, 8.3–32.0) in the lenalidomide 5-mg, 10-mg, and placebo groups, respectively. This

increased to 35% (95% CI, 21.4–54.6), 31% (95% CI, 18.1–48.8), and 43.3% (95% CI, 27.6–63.1), respectively, at the estimated 4-year mark. The median OS among the lenalidomide 5-mg, 10-mg, and placebo groups (3.5 vs. 4.0 vs. 2.9 years, respectively) was not statistically significantly different; however, median survival was significantly longer in patients who achieved RBC-TI (5.7 years; 95% CI, 3.2–no response) compared to non-responders (2.7 years; 95% CI, 2.0–4.7). The most common grade 3 or 4 adverse events were myelosuppression and deep vein thrombosis (DVT). Grade 3 or 4 neutropenia was reported in 77%, 75%, and 16% of patients and thrombocytopenia occurred in 37%, 38%, and 2% of patients in the lenalidomide 5-mg, 10-mg, and placebo arms, respectively. Grade 3 or 4 DVT occurred in 3 patients in the lenalidomide 10-mg arm and in one patient in the placebo arm.³⁵⁷

A comparative analysis evaluated outcomes of patients with RBC-TD IPSS low/int-1-risk MDS with del(5q) receiving lenalidomide (based on data from the two aforementioned trials [$n = 295$]) compared with no treatment (based on data from untreated patients in a multicenter registry [$n = 125$]).³⁵⁸ Untreated patients from the registry had received BSC, including RBC transfusion, iron chelation therapy, and/or ESAs. The 2-year cumulative incidence of AML progression was 7% with lenalidomide and 12% in the untreated cohort; the corresponding 5-year rates were 23% and 20%, respectively; the median time to AML progression had not been reached in either cohort at the time of publication. Lenalidomide was not a significant factor for AML progression in either univariate or multivariate analyses. The 2-year OS probabilities were 90% with lenalidomide and 74% in the untreated cohort; the corresponding 5-year OS probabilities were 54% and 40.5%, respectively, with a median OS of 5.2 years and 3.8 years ($P = .755$).³⁵⁸ Based on multivariate analysis using Cox proportional hazard models with left truncation, lenalidomide was associated with a significantly decreased risk of death compared with no treatment (HR, 0.597; 95% CI, 0.399–0.894;



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

$P = .012$). Other independent factors associated with a decreased risk of death were female sex, higher hemoglobin levels, and higher platelet counts. Conversely, independent factors associated with increased risk of death included older age and greater RBC transfusion burden.³⁵⁸

A phase II study evaluated lenalidomide treatment in patients with RBC-TD (N = 214) low- or int-1–risk MDS without del(5q).³⁵⁹ Results showed that 26% of the patients with non-del(5q) (56 of 214) achieved TI after a median of 4.8 weeks of treatment. TI continued for a median duration of 41 weeks. The median rise in hemoglobin was 3.2 g/dL (range, 1.0–9.8 g/dL) for those achieving TI. A 50% or greater reduction in transfusion requirement was noted in an additional 37 patients (17%), yielding an overall rate of hematologic improvement of 43%. The most common grade 3 or 4 adverse events were neutropenia (30%) and thrombocytopenia (25%).

An international phase III study of 239 patients with IPSS low- or int-1–risk MDS and RBC-TD and lacking the del(5q) abnormality evaluated the role of lenalidomide treatment.³⁴² Patients receiving lenalidomide (n = 160) compared to placebo (n = 79) had a higher rate of RBC-TI (26.9% vs. 2.5%; $P < .001$) that lasted a median duration of 31 weeks (95% CI, 20.7–59.1 weeks). TI persisting >8 weeks was seen in 27% of patients receiving lenalidomide versus 2.5% of patients in the placebo cohort ($P < .001$). Overall, 90% of patients had disease that responded to therapy within 16 weeks. Transfusion reduction of four or more units of packed RBCs was seen in 22% of lenalidomide-treated patients while no reduction was seen in the placebo group. Incidence of treatment-related mortality was 2.5% in both groups; however, the incidence of myelosuppression was higher in the lenalidomide-treated group. In comparing the patients receiving lenalidomide versus placebo, the incidence of grade 3 or 4 neutropenia was 61.9% versus 12.7%, respectively, and the rate of thrombocytopenia was 35.6% versus 3.8%, respectively.³⁴² Further evaluation in more

extended clinical trials is needed to determine the efficacy of this drug and other agents for patients with non-del(5q) MDS, particularly addressing the characterization of the subgroup of patients with MDS who responded to lenalidomide. The NCCN Guidelines Panel recommends lenalidomide be considered for patients with symptomatically anemic non-del(5q) MDS with anemia that did not respond to prior therapy.

A phase III randomized trial in patients with lower-risk, ESA-refractory, non-del(5q) MDS compared lenalidomide alone (10 mg/day for 21 days every 28 days) with patients receiving lenalidomide in conjunction with epoetin alfa (60,000 U/wk).³⁶⁰ Erythroid response after 4 treatment cycles was 23.1% (95% CI, 13.5–35.2) versus 39.4% (95% CI, 27.6–52.2; $P = .044$), respectively. Overall RBC-TI was not statistically different between groups (13.8% vs. 24.2%; $P = .13$). However, in a subgroup analysis that excluded patients with heavy RBC transfusion dependence (defined as receiving greater than 4 RBC units per 8 weeks) a statistically significant improvement was seen with the addition of epoetin alfa (47% vs. 16%; $P = .04$), suggesting that lenalidomide may restore sensitivity of MDS erythroid precursors to Epo.³⁶⁰ Another phase III trial also reported a significantly higher major erythroid response in patients with lower-risk MDS lacking del(5q) treated with 4 cycles of lenalidomide in conjunction with epoetin alfa compared to lenalidomide monotherapy (28.3% vs. 11.5%; $P = .004$).³⁶¹ The median duration of the major erythroid response for the combination treatment was 23.8 months versus 13.0 months for the lenalidomide arm.

High-Intensity Therapy

High-intensity therapy includes intensive induction chemotherapy or HCT.^{4,362} Although these approaches have the potential to change the natural history of the disease, there is an attendant greater risk of regimen-related morbidity and mortality. The Panel recommends that such treatments be given in the context of clinical trials. Comparative studies



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

have not shown benefit between the different intensive chemotherapy regimens (including idarubicin-, cytarabine-, fludarabine-, and topotecan-based regimens) in MDS.³⁶³

A high degree of multi-drug resistance occurs in marrow hematopoietic precursors from patients with advanced MDS³⁶⁴ and is associated with decreased responses and shorter response durations in patients treated with many of the standard chemotherapy induction regimens. Thus, chemotherapeutic agents used to treat “resistant-type” AML, and agents that modulate this resistance, are now being evaluated for the treatment of patients with advanced MDS. Ongoing clinical trials evaluating multi-drug resistance modulators are important, as both positive^{365,366} and negative³⁶⁷ studies have been published.

Allogeneic HCT from an HLA-matched sibling, unrelated donor, haploidentical donor, or cord blood donor is a preferred approach for treating select patients with MDS, particularly those with high-risk disease.³⁶⁸⁻³⁷⁸ This includes both standard and RIC strategies.

A multicenter study investigating the outcomes of patients with IPSS int-2 or high MDS who were eligible for RIC allo-transplant found a survival advantage for patients who underwent transplantation.³⁷⁹ At 3 years, an intention-to-treat analysis revealed that the adjusted OS rate in patients aged 50 to 75 years was 47.9% (95% CI, 41.3%–54.1%) and 26.6% (95% CI, 18.4%–35.6%; $P = .0001$) for those in the donor arm (expected to undergo reduced-intensity conditioning HCT, $n = 260$) and the no-donor arm (expected to receive HMA therapy or best supportive care, $n = 124$), respectively. In addition, at the same time point, the leukemia-free survival rate was 35.8% (95% CI, 29.8%–41.8%) versus 20.6% (95% CI, 13.3%–29.1%; $P = .003$), respectively. Subgroup analyses showed that there were no differences in outcomes by age ≤ 65 years versus age > 65 years. However, since ~34% of patients in both arms had disease that did not

respond to HMAs, it is not surprising that the donor arm results appeared better.

Another study examined retrospectively the outcomes of patients with high-risk MDS or secondary AML who underwent transplantation without prior cytoreductive therapy ($n = 67$) compared to those who received cytoreductive therapy in the form of induction chemotherapy ($n = 64$) or HMAs ($n = 34$) prior to transplantation.³⁸⁰ Patients had a blast count of $\geq 5\%$ in the bone marrow. Reduced-intensity conditioning was applied before stem cell infusion in 68% of patients. Compared to the other groups, a higher percentage of patients in the HMA group (85%) were treated with a reduced-intensity conditioning regimen, which is likely due to the difference in age. Multivariate analyses revealed that the type of pretransplant treatment did not impact the OS, relapse-free survival (RFS), and non-relapse mortality. However, cytogenetics, reduced-intensity conditioning and the use of an unrelated donor were found to be predictors of negative outcomes. At 5 years, there was no difference in OS (61%, 50%, and 45% respectively; $P = .116$) and relapse-free survival (38%, 41%, and 38% respectively; $P = .926$) between the 3 groups. The OS ($P = .971$) and RFS ($P = .883$) were similar in patients with blasts $< 10\%$ or with blasts $\geq 10\%$ in the bone marrow who underwent transplantation without prior cytoreductive therapy.

A randomized trial in patients with MDS or AML determined that myeloablative conditioning resulted in a higher rate of transplanted-related mortality at 4 years (25.1% vs. 9.9% for reduced-intensity conditioning; $P < .001$).³⁸¹ However, as the risk of relapse is greater in those who received reduced-intensity conditioning (HR, 4.06; $P < .001$), patients in the myeloablative conditioning arm fared better in terms of OS (HR, 1.54; $P = .03$).

Early referral for transplant evaluation is recommended to allow moving to transplant efficiently. Pre-transplant debulking therapy to reduce marrow



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

blasts to < 5% blasts with the goal of reducing post-transplant relapse is recommended, although the optimum strategy has not been determined. To reduce the disease burden pre-transplant is particularly important in patients who will receive a reduced-intensity conditioning regimen.³⁴¹ At some centers, failure to achieve <5% blasts with cytoreduction did not preclude from proceeding to transplant, as these patients appeared to derive survival benefit from transplant.^{379,380}

An argument in favor of pre-transplant cytoreduction was provided by Festuccia et al³⁴¹ who showed that the presence of minimal identifiable disease (MID) prior to transplantation in patients with MDS or AML arising from MDS impacted prognosis following transplantation. In patients with MID positive by cytogenetics, irrespective of positivity by flow cytometry, the overall mortality risk was higher in those who underwent low-intensity conditioning compared to those who underwent high-intensity conditioning. However, in patients with MID negative status, as determined by both cytogenetics and flow cytometry, the risk of mortality with low- and high-intensity conditioning regimens was similar. It is important to note that this study did not specifically examine outcomes in patients who proceeded to transplant without cytoreductive therapy. In patients with a MID positive status, as assessed by both cytogenetics and flow cytometry, the risk of relapse was higher in those who underwent low-intensity conditioning, as opposed to those who underwent high-intensity conditioning. As the MID classification can help to identify patient subgroups who may have better outcomes with high- or low-intensity conditioning, the authors propose to consider the presence of MID to help determine the intensity of the conditioning regimen for patients being considered for transplant.

For higher-risk MDS, AzaC, decitabine, oral decitabine and cedazuridine, or other therapies may be used as a bridge to transplantation. These agents should not be used to delay HCT in patients who have available donors. A clinical trial followed by allo-HCT is another option. In patients

with disease relapse after a prolonged remission following the first transplant, a second transplant or donor lymphocyte infusion immunobased therapy may be considered. Allogeneic HCT may also be considered in select patients with lower-risk MDS (IPSS int-1, IPSS-R, and WPSS intermediate) with severe cytopenias. Whether transplants should be performed before or after patients achieve remission following induction chemotherapy has not been prospectively established.³⁸² Comparative clinical trials are needed to address these issues.

Targeted Therapy

Emerging data have shown efficacy of novel agents, including venetoclax, a B-cell lymphoma 2 (BCL-2) inhibitor, in combination with HMAs or targeted IDH1/2 inhibitors for cytoreduction for patients with high-risk MDS.³⁸³⁻³⁸⁶ When used as cytoreduction for MDS in combination with an HMA, venetoclax has been effectively given for 14 days in monthly courses.³⁸⁴ Repeating the bone marrow evaluation after 1 to 2 cycles is important to clarify the recovery of hematopoiesis and potential requirement for further therapy. Clinical trials are preferred (NCT04401748).

As overexpression of the BCL-2 protein has been linked to disease progression in MDS, studies are ongoing to investigate the efficacy and safety of venetoclax in patients with MDS either first-line or refractory or resistant to HMAs.^{384,387} Abstract data from a phase Ib study investigating the combination of venetoclax and AzaC for 14 days in a 28-day cycle in upfront higher-risk MDS (IPSS-R intermediate, high, or very-high) resulted in an ORR, median OS, and median complete remission duration of 29.9%, 26 months, and 16.6 months.³⁸⁴ The most frequent grade ≥3 treatment-emergent adverse events were neutropenia (48.6%), thrombocytopenia (43.0%), febrile neutropenia (42.1%), and anemia (34.6%). In a study exploring venetoclax in combination with AzaC in patients with relapsed/refractory MDS, results showed a modified ORR of



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

39% and a median OS of 12.6 months.³⁸⁵ Febrile neutropenia (34%), thrombocytopenia (32%), neutropenia (27%), and anemia (18%) were the most frequent grade ≥3 hematologic adverse events.

Mutations in the isocitrate dehydrogenase 1 (*IDH1*) or 2 (*IDH2*) genes occur in approximately 4% to 12% of patients with MDS.³⁸⁸⁻³⁹⁰ Ongoing clinical trials are investigating the efficacy of targeted *IDH1/2* inhibitors in patients with MDS (clinicaltrials.gov NCT03503409, NCT03471260, and NCT03744390).³⁹¹⁻³⁹³ Substudy data from a phase I trial investigating the safety and efficacy of ivosidenib in 18 evaluable patients with relapsed or refractory MDS with *mIDH* demonstrated an ORR of 83.3% and an approximate median OS of 36 months.³⁹⁴ Additionally, 71.4% and 75.0% of patients with RBC-TD and platelet transfusion-dependence, respectively, achieved transfusion independence. Emerging data have also shown the utility of olutasidenib for treatment patients with *IDH1* mutations.³⁸⁶ In one study, 33% of patients with intermediate-, high-, or very high-risk MDS treated with olutasidenib monotherapy achieved an overall response, while 69% of patients treated with olutasidenib and AzaC achieved an overall response.

A phase II study in patients with higher-risk *IDH-2* mutated MDS determined an ORR and median OS of 74% and 26 months, respectively, in newly diagnosed patients treated with enasidenib and AzaC, compared to 35% and 20 months, respectively, in patients who were previously treated with an HMA.³⁹⁵ Across both groups, the most frequent adverse events included neutropenia (40%), nausea (36%), and constipation (32%).

Recommended Treatment Approaches

Therapy for Lower-Risk Disease (IPSS Low, Intermediate-1; IPSS-R Very Low, Low, Intermediate; or WPSS Very Low, Low, Intermediate)

Regarding the therapeutic options for patients with lower-risk MDS with clinically significant cytopenias, the NCCN Guidelines Panel recommends stratifying these patients into several groups. For patients without symptomatic anemia who have clinically relevant thrombocytopenia or neutropenia, recommended treatment options include a clinical trial, AzaC, decitabine, oral decitabine and cedazuridine, or IST, with or without eltrombopag (useful in certain circumstances) for select patients. IST is recommended for patients generally aged ≤60 years and with ≤5% marrow blasts, or those with hypocellular marrows, PNH clone positivity, or STAT-3 mutant cytotoxic T-cell clones. IST includes equine ATG, with or without cyclosporin A. Additionally, for severe thrombocytopenia, eltrombopag alone could be considered. Some studies have shown clinical benefit with low doses of AzaC or decitabine.³⁹⁶ If there is disease progression or no response following initial treatment, HMAs should be considered, if not previously used. Eltrombopag or romiplostim can be considered for patients with severe or refractory thrombocytopenia.^{258,262,397} Ivosidenib is recommended for *mIDH1* MDS. In the absence of *mIDH1*, clinical trial as well as consideration of allogeneic HCT in select patients with lower-risk MDS (IPSS int-1, IPSS-R, and WPSS intermediate MDS) with severe cytopenias are recommended.

For patients with del(5q) chromosomal abnormalities alone or with one other cytogenetic abnormality, except those involving chromosome 7, and symptomatic anemia, lenalidomide is a category 1 preferred option if sEPO is >500 mU/mL. If sEPO is ≤500 mU/mL, lenalidomide is a preferred regimen and epoetin alfa and darbepoetin alfa are other recommended regimens. An FDA-approved biosimilar is an appropriate substitute for epoetin alfa. Studies have shown the relative safety of lenalidomide in



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

these patients and improved QOL outcomes in randomized clinical trials.^{398,399} The recommended initial dose of lenalidomide in this setting is 10 mg/day for 21 days, every 28 days, or 28 days monthly; response should be assessed 2 to 4 months after initiation of treatment. In patients with a clinically significant decrease in neutrophil or platelet counts, caution is required and may warrant either use of a modified dose of lenalidomide. In the previously discussed phase III trial with lenalidomide in patients with del(5q), patients with low neutrophil counts (<500 cells/mcL) or platelet counts (<25,000 cells/mcL) were excluded from the study.³⁵⁷ Patients with monosomy 7 are an exception and should be treated in the higher prognostic risk category. Exposure to lenalidomide has been associated with an elevated risk of *TP53*-mutated clones.⁴⁰⁰ Additional consideration for and/or closer monitoring of particular patients is warranted. If no response is seen to lenalidomide or ESAs, these patients should follow treatment options (with the exception of imetelstat) for patients without the del(5q) abnormality, with sEPO levels >500 mU/mL, and with poor probability to respond to IST (see *Management of Lower-Risk Disease* in the algorithm).

Patients without the del(5q) abnormality, alone or with one other cytogenetic abnormality and with symptomatic anemia, are categorized on the basis of ring sideroblasts percentage and sEPO levels. In patients with no del(5q), with or without other cytogenetic abnormalities, with ≥15% ring sideroblasts, or ≥5% ring sideroblasts with an *SF3B1* mutation, luspatercept-aamt (category 1); and imetelstat (if sEPO >500 mU/mL [ineligible for ESAs]) are first-line options. The starting dose of luspatercept-aamt is 1 mg/kg every 3 weeks, which may be increased to 1.33 mg/kg every 3 weeks if RBC transfusions are still needed after at least 2 consecutive doses (6 weeks) at the 1 mg/kg starting dose. The dose may be further increased to 1.75 mg/kg every 3 weeks if RBC transfusions are still needed after at least 2 consecutive doses (6 weeks) at the 1.33 mg/kg dose. The initial dosing of imetelstat is 7.1 mg/kg IV

monthly with potential dose decrements since frequent transient thrombocytopenia and neutropenia may occur. The starting platelet and neutrophil levels should be ≥75,000 and ≥1,500, respectively.³¹⁷ If there is no response by 3 to 6 months of treatment with luspatercept-aamt and the sEPO level is ≤500 mU/mL, imetelstat (category 1), as well as epoetin alfa with or without G-CSF or darbepoetin alfa with or without G-CSF, are recommended options. If the sEPO level is >500 mU/mL, imetelstat or consideration of treatment with lenalidomide is recommended. If there is no response by 3 to 6 months of treatment in patients who received first-line imetelstat, lenalidomide should be considered.

The epoetin alfa dose required is 40,000 to 60,000 SC units 1 to 2 times per week. Darbepoetin alfa should be given subcutaneously at a dose of 150 to 300 mcg every other week. For a lack of response, the dose may be escalated. At some NCCN member institutions, darbepoetin alfa has been given at doses up to 500 mcg every other week. Erythroid responses generally occur within 6 to 8 weeks of treatment.^{300,401-403} A prompter response may be obtained with a higher starting dose. The above-recommended dose for epoetin alfa is much higher than the dose needed to treat renal causes of anemia wherein marrow responsiveness would be relatively normal. However, if a response occurs at the higher dose, the recommendation is to attempt a decrease to the lowest effective dose. Evidence suggests that G-CSF (and, to a lesser extent, GM-CSF) has synergistic erythropoietic activity when used in combination and markedly enhances the erythroid response rates due to enhanced survival of red cell precursors.^{300,401,402,404} This is particularly evident for patients with ≥15% ring sideroblasts in the marrow (and sEPO level ≤500 mU/mL), as the very low response rates to epoetin alfa or darbepoetin alone in this subgroup are markedly enhanced when combined with G-CSF.^{300,402} For the erythroid synergistic effect, relatively low doses of G-CSF are needed to help normalize the neutrophil count in patients who initially have



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

neutropenia or to double the neutrophil count in patients who do not initially have neutropenia. For this purpose, an average of 1 to 2 mcg/kg SC G-CSF is administered either daily or 1 to 2 times per week.^{300,401,402,404}

If no response is seen by 6 to 8 weeks of treatment with ESAs with or without G-CSF or by 3 to 6 months of treatment with imetelstat or lenalidomide, ivosidenib (if mIDH1), a clinical trial, AzaC (preferred), imetelstat if not previously used (other recommended), decitabine (other recommended), oral decitabine and cedazuridine (other recommended), or consideration of lenalidomide (useful in certain circumstances) are recommended. If there is no response within 6 cycles of AzaC or 4 cycles of decitabine or oral decitabine and cedazuridine or intolerance, ivosidenib is recommended for mIDH1 MDS. A clinical trial or consideration of HCT for select patients are recommended for patients without mIDH1.

Epoetin alfa or darbepoetin alfa are preferred options and luspatercept-aamt is an other recommended option for patients with no del(5q), with or without other cytogenetic abnormalities, with ring sideroblasts <15% (or ring sideroblasts <5% with an SF3B1 mutation) and sEPO ≤500 mU/mL. Patients with normal cytogenetics, <15% ring sideroblasts, and sEPO levels of ≤500 mU/mL may respond to Epo if relatively high doses are administered.^{246,404,405} Iron repletion needs to be verified before instituting epoetin alfa or darbepoetin alfa therapy. If no response occurs with ESAs alone (despite adequate iron stores) after 6 to 8 weeks or with luspatercept-aamt after 3 to 6 months, G-CSF or lenalidomide may be combined with ESAs. Imetelstat (category 1) and luspatercept-aamt (if not previously used) are also options.

If no response occurs following subsequent treatment with ESAs, with or without lenalidomide or G-CSF, within 6 to 8 weeks of treatment, or following subsequent treatment with imetelstat or luspatercept-aamt within 3 to 6 months of treatment, treatment should be discontinued. Patients

should follow treatment options for patients without the del(5q) abnormality, with sEPO >500 mU/mL, and with poor probability to respond to IST (see *Management of Lower-Risk Disease* in the algorithm). Imetelstat (category 1), if not previously used, and ivosidenib (for mIDH1) are also options. A validated decision model has been developed for predicting erythroid responses to Epo plus G-CSF based on the patient's basal sEPO level and number of previous RBC transfusions.^{402,406} This cytokine treatment is not suggested for patients with endogenous sEPO levels >500 mU/mL due to the very low erythroid response rate to these drugs in this patient population.

Patients with symptomatic anemia with no del(5q), with or without other cytogenetic abnormalities, with ring sideroblasts <15% (or ring sideroblasts <5% with an SF3B1 mutation) and sEPO levels >500 mU/mL should be evaluated to determine whether they would be good candidates for IST (generally ≤60 years and with ≤5% marrow blasts, or with hypocellular marrows, PNH clone positivity, or STAT3-mutant cytotoxic T-cell clones). For patients with disease that has a good probability to respond to IST, IST options include ATG plus cyclosporin A, with or without eltrombopag. ATG may be omitted when clinically indicated. If there is no response within 3 to 6 months or if the patients have disease that has a poor probability to respond to IST, a clinical trial, treatment with AzaC (preferred), imetelstat if not previously used (other recommended), decitabine (other recommended), oral decitabine and cedazuridine (other recommended), or consideration of lenalidomide (useful in certain circumstances), are recommended. Oral decitabine and cedazuridine could be a substitution for IV decitabine in patients with IPSS Intermediate-1 and above.^{332,407} A phase II prospective study of patients with MDS, that is IPSS low or int-1, with symptomatic anemia with disease that was not expected to respond or that failed to respond to Epo, showed that 5-day AzaC courses were well-tolerated.⁴⁰⁸ Although neutropenia and thrombocytopenia were adverse events (47% and 19% of patients,



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Myelodysplastic Syndromes

respectively), these toxicities were transient. Other non-hematologic toxicities were mild. AzaC treatment was effective in 60% of patients in the study. In addition, 3-day cycles of HMAs have also been beneficial for patients with lower-risk MDS with anemia.³⁹⁶

If there is no response within 6 cycles of AzaC or 4 cycles of decitabine or oral decitabine and cedazuridine or intolerance, ivosidenib is recommended for m/DH1 MDS. A clinical trial or consideration of HCT for select patients are recommended for patients without m/DH1. Emerging data are demonstrating effectiveness of enasidenib for patients with MDS with IDH2 mutations⁴⁰⁹ (see *Targeted Therapy*).

While these guidelines provide a framework in which to treat patients with MDS, careful monitoring for disease progression and consideration of the patient's preferences remain major factors in the decision and timing of the treatment regimen initiated.

Therapy for Higher-Risk Disease (IPSS Intermediate-2, High; IPSS-R Intermediate, High, Very High; or WPSS High, Very High)

Treatment for higher-risk disease is dependent on whether patients are possible candidates for intensive therapy (eg, allogeneic HCT, intensive chemotherapy). Clinical features relevant for this determination include patient age (including patients up to 75 years of age), performance status, absence of major comorbid conditions, psychosocial status, patient preference, and availability of a suitable donor and caregiver. Patients may be taken immediately to transplant or bridging therapy can be used to decrease marrow blasts to an acceptable level prior to transplant.³⁷⁹ The patient's personal preference for type of therapy needs particular consideration. Regardless, supportive care should be provided for all patients.

Intensive Therapy

Allogeneic Hematopoietic Cell Transplantation

Allogeneic HCT is recommended for eligible patients. Treatment with AzaC, decitabine, oral decitabine and cedazuridine, high-intensity chemotherapy, or enrollment in a clinical trial prior to allogeneic HCT are also options. Single-agent ivosidenib may be considered for m/DH1 MDS if there is no response following treatment with HMAs or high-intensity chemotherapy. For patients who are transplant candidates, an HLA-matched sibling or HLA-matched unrelated donor can be considered. Results with HLA-matched unrelated donors have improved to levels comparable to those obtained with HLA-matched siblings. With the increasing use of cord blood or HLA-haploidentical related donors, HCT has become a viable option for many patients. High-dose conditioning is typically used for younger patients, whereas RIC for HCT is generally the strategy in older individuals.⁴¹⁰

To aid therapeutic decision-making regarding the timing and selection of patients with MDS for HCT, a study compared outcomes with HLA-matched sibling HCT in patients with MDS ≤60 years of age to data in patients with MDS who did not undergo transplantation from the IMRAW/IPSS database.⁴¹¹ Using a Markov decision analysis, this investigation indicated that patients with IPSS int-2 and high-risk MDS ≤60 years of age had the longest life expectancy if transplanted (from HLA-identical siblings) soon after diagnosis, whereas patients with IPSS low risk MDS had the best outlook if HCT was delayed until MDS progressed. For patients in the int-1–risk group, there was only a slight gain in life expectancy if HCT was delayed; therefore, decisions should be made on an individual basis (eg, dependent on platelet or neutrophil counts).⁴¹¹ A retrospective study evaluated the impact of the WHO classification and WPSS on the outcome of patients who underwent allogeneic HCT.²⁰⁵ The data suggest that patients with lower-risk MDS (based on WPSS risk score) do very well following allogeneic HCT, with a



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Myelodysplastic Syndromes

5-year OS of 80%. With increasing WPSS scores, the probability of 5-year survival after HCT declined progressively to 65% (intermediate risk), 40% (high risk), and 15% (very high risk).²⁰⁵

Based on data regarding RIC for transplantation from two studies^{412,413} and two comprehensive reviews of the field,^{414,415} patient age and disease status generally dictated the type of conditioning. Patients >55 or 65 years of age, particularly if they had <10% marrow myeloblasts, generally received RIC; if the blast count was high, pre-HCT debulking therapy was often given. Younger patients, regardless of marrow blast burden, most frequently received high-dose conditioning. Variations on these approaches would be considered by the individual transplant physician based on patient features and the specific regimen used at that center. Some general recommendations have been presented in a review article.⁴¹⁶

There are limited data regarding the use of allogeneic HCT in older adults with MDS; however, studies suggest that age alone should not be an exclusionary factor for eligibility. In a prospective allogeneic transplant trial using nonmyeloablative conditioning, 372 patients between ages 60 and 75 years with hematologic malignancies (AML, MDS, chronic lymphocytic leukemia, lymphoma, and multiple myeloma) were shown to have no association between age and non-relapse mortality, OS, and PFS.⁴¹⁷ The study supports the use of comorbidities and disease status, rather than age alone, as criteria for determining the eligibility of patients for allogeneic HCT.

Other retrospective studies have also evaluated transplant-related mortality in older patients with MDS receiving RIC for allogeneic transplant.^{418,419} No increase in mortality was seen in either study. In a retrospective analysis of 514 patients with de novo MDS (aged 60–70 years), RIC allogeneic transplants were not associated with improved life expectancy for patients with low or int-1 IPSS MDS compared to other

non-transplant therapies. However, a potential improvement in life expectancy was seen in patients with int-2– or high-risk IPSS MDS.⁴²⁰ It is recognized that there are even fewer data available in regard to patients who are >75 years of age.

Intensive Chemotherapy

For patients eligible for intensive therapy but lacking a donor hematopoietic cell source, or for patients in whom the marrow blast count requires reduction, consideration should be given to the use of intensive induction chemotherapy.⁴²¹ Although the response rate and durability are lower than for standard AML, this treatment (particularly in clinical trials with novel agents) could be beneficial in some patients. For patients with a potential hematopoietic cell donor who require reduction of tumor burden (ie, to decrease the marrow blast count), achievement of even a partial remission may be sufficient to permit the HCT.

Relapse after allo-HCT or No Response

The Panel recommends repeating molecular testing in order to identify targetable mutations. In patients with disease relapse after a prolonged remission following the first transplant or with no response, a second transplant or donor lymphocyte infusion immuno-based therapy may be considered. Enrollment in a clinical trial or HMAs (AzaC, decitabine, oral decitabine and cedazuridine) are also options. If there is no response to treatment or the disease relapses, enrollment in a clinical trial or supportive care is recommended.

Non-Intensive Therapy

For patients with higher-risk MDS who do not have a suitable transplant donor and who are not candidates for intensive therapy, the use of AzaC (preferred regimen), decitabine (other recommended regimen), oral decitabine and cedazuridine (other recommended regimen), or a relevant clinical trial are recommended. Oral decitabine and cedazuridine could be a substitution for IV decitabine in patients with IPSS Intermediate-1 and



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

above.^{332,407} Ivosidenib is recommended for m/DH1 MDS if there is no response within 6 cycles of azacitidine or 4 cycles of decitabine or oral decitabine and cedazuridine or intolerance. Enrollment in a clinical trial is recommended if there is no response to ivosidenib within 3 to 6 months or for those without m/DH1.

In a phase III, international, multicenter, controlled, open-label study (AZA-001), 358 patients with higher-risk MDS were randomly assigned 1:1 to receive azacitidine (75 mg/m² daily for 7 days every 28 days) or conventional care (best supportive care, low-dose cytarabine, or intensive chemotherapy).³¹⁸ With a median follow-up of 21.1 months (interquartile range [IQR], 15.1–26.9), treatment with AzaC led to a higher median OS (24.5 months [9.9 months—not reached]) when compared to conventional care (15.0 months [5.6–24.1 months]; HR, 0.58; 95% CI, 0.43–0.77; $P = .0001$). At 2 years, 50.8% (95% CI, 42.1%–58.8%) of patients receiving AzaC were alive compared with 26.2% (18.7%–34.3%) of patients receiving conventional care group ($P < .0001$). The most frequent grade 3–4 adverse events for all treatments were peripheral cytopenias. These data demonstrated that treatment with AzaC increased OS in patients with higher-risk MDS relative to conventional care.

Results from a phase III trial comparing decitabine to BSC in patients with higher-risk disease who were ineligible for intensive chemotherapy demonstrated a statistically significant improvement in PFS and reduced AML transformation; improvements in OS and AML-free survivals were also seen, although they did not reach statistical significance.³¹⁹ AzaC, decitabine, or oral decitabine and cedazuridine should be continued for at least 6 cycles of AzaC or 4 cycles of decitabine or oral decitabine and cedazuridine to assess response to these agents. For patients who show clinical benefit, treatment with HMs should be continued as maintenance therapy.

Two further reports from the phase III, international, multicenter, randomized AZA-001 trial have evaluated AzaC compared to conventional care regimens (CCR) in patients with higher-risk MDS. Patients randomized to the CCR group received the most appropriate of the three protocol-specified CCR options, including AzaC, intensive chemotherapy, or BSC.^{422,423} The OS was increased with AzaC treatment compared to CCR (HR, 0.58; 95% CI, 0.43–0.77; $P < .001$), and a greater number of patients achieved hematologic improvement (49% vs. 29%; $P < .0001$).⁴²² The earlier report from the same trial showed improved OS and tolerability in patients aged ≥ 75 years with good performance status.⁴²³ It should be noted that, to date, no head-to-head trials have compared AzaC with decitabine. Therefore, the Panel preferentially recommends AzaC (category 1) versus decitabine or oral decitabine and cedazuridine based on data from the phase III trial that showed superior median survival with AzaC compared to BSC.

Supportive Care Only

For patients with adverse clinical features or disease progression despite therapy and the absence of reasonable specific anti-tumor therapy, adequate supportive care should be maintained.

Summary

The NCCN Guidelines are based on extensive evaluation of the reviewed risk-based data and indicate current approaches for the management of MDS. Drugs approved by the FDA for treating specific patients with MDS include lenalidomide for patients with del(5q) cytogenetic abnormalities; AzaC, decitabine, or the oral combination of decitabine and cedazuridine for treating higher-risk MDS or MDS that is non-responsive; deferasirox and deferoxamine for iron chelation in the treatment of iron overload; luspatercept-aamt for treating ring sideroblastic MDS in those with no response to prior ESA treatment or for treating lower-risk MDS; imetelstat for treating lower-risk MDS in patients with no response or loss



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of response to ESAs or for those who are ineligible for ESAs; and ivosidenib for *mid*H MDS. However, as a substantial proportion of subsets of patients with MDS lack effective treatment for their cytopenias or for altering disease natural history, clinical trials with these and other novel therapeutic agents, along with supportive care, remain the hallmark of disease management. Evaluating the role of thrombopoietic cytokines for the management of thrombocytopenia in MDS and determining the effects of therapeutic interventions on QOL are important issues needing investigation.^{401,403,406,424,425} Progress toward improving the management of MDS has occurred over the past few years and more advances are anticipated with these guidelines providing a framework for coordination of comparative clinical trials.

Discussion
update in
progress



NCCN Guidelines Version 1.2025

Myelodysplastic Syndromes

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NCCN Guidelines Version 1.2025

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Myelodysplastic Syndromes

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