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Evidence-based algorithm to treat patients with proximal humerus fractures—a prospective study with early clinical and overall performance results

Christian Spross, MD*, Jan Meester, MD, Ruben A. Mazzucchelli, MD, Gábor J. Puskás, MD, Vilijam Zdravkovic, MD, Bernhard Jost, MD

Department of Orthopaedic Surgery and Traumatology, St. Gallen, Switzerland

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Background: On the basis of patients' demands, bone quality, and fracture type, we developed an evidence-based treatment algorithm for proximal humerus fractures (PHF) that includes all treatment modalities from open reduction and internal fixation, hemiprosthesis, to reverse total shoulder arthroplasty. This study was done to assess its feasibility and early clinical outcome.
Materials and methods: Patients with isolated PHF in 2014 and 2015 were included in this prospective study. The quality of life (EQ-5D) and the level of autonomy before injury were recorded. The fractures were classified and local bone quality was measured. When possible, patients were treated according to the algorithm. Radiographic and clinical follow-up—Constant score, subjective shoulder value, and EQ-5D—took place after 3 months and 1 year. The rate of unplanned surgery was analyzed.
Results: A total of 192 patients (mean age 66 years; 58 male, 134 female) were included. Of these, 160 (83%) were treated according to the algorithm. In total, 132 patients were treated conservatively, 36 with open reduction and internal fixation and 24 with reverse total shoulder arthroplasty or hemiarthroplasty. Generally, the mean EQ-5D before trauma and 1 year after treatment was equal to 0.88 to 0.9 points. After 1 year, the overall mean relative Constant score was 95% and mean subjective shoulder value 84%. Unplanned surgery was necessary in 21 patients.
Conclusion: This comprehensive algorithm is designed as a noncompulsory treatment guideline for PHF, which prioritize the patient's demands and biology. The high adherence proves that it is a helpful tool for decision making. Furthermore, this algorithm leads to very satisfying overall results with low complication and revision rates.
Level of evidence: Level II; Prospective Cohort Design; Treatment Study

Keywords: Treatment algorithm; proximal humerus fracture; conservative treatment; angular stable ORIF; hemiarthroplasty; reverse total shoulder arthroplasty

This study was approved by the Ethical Committee of Kanton St. Gallen, Switzerland (Ref. BASEC No. 2016-01023).

*Reprint requests: Christian Spross, MD, Kantonsspital St. Gallen, Rorschacherstr 95, St. Gallen 9007, Switzerland.
E-mail address: christianspross@netdot.ch (C. Spross).

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With the introduction of promising preliminary results using anatomically preshaped locking plates for proximal humerus fractures (PHF),[23,26,58] these became the mainstay of operative treatment.[1,6,13,15,50,58] However, the increased use of these plates is accompanied by high complication rates[30,32,41,54,55,58] that might result in difficult revision cases with limited outcome.[22,29] Thus, the operative treatment for PHF has been questioned, and randomized controlled trials have not shown any significant functional benefit for surgery compared with nonsurgical treatment.[18,17,36,37,44,48] Although such studies provide high evidence, they often result in fragmented knowledge for certain fracture types or specific treatment options not taking into consideration any further patient-specific factors. In our opinion and as a consequence of these studies, the treatment strategy for PHF should not only be based on the fracture type but also on individual factors such as patients' demands and bone quality.[7,30,32,35,56] Therefore, we developed an evidence-based algorithm to treat PHF.[51,52] It relies on the available evidence on PHF, which has been summarized and outlined in detail in a book chapter on PHF.[51] The algorithm prioritizes patients' demands and biology and includes all treatment options from conservative to reverse total shoulder arthroplasty (RTSA).

The algorithm

The first part of the algorithm considers young and active patients usually up to the age of 65 years (Fig. 1). In these patients, the aim is to achieve maximal shoulder function, according to the current literature.[3,4,13,14,19,20,25,31,42,43,45,51]

The second part of the algorithm considers elderly patients, usually older than 65 years (Fig. 2).[51] In the first step, their activity level and general health status are assessed. If the patients come from a nursing home, they are treated conservatively, the aim being pain relief[17,18,36,37,44] (right side of Fig. 2). If the patients are still active and independent before the fracture, the goal is to achieve maximal shoulder

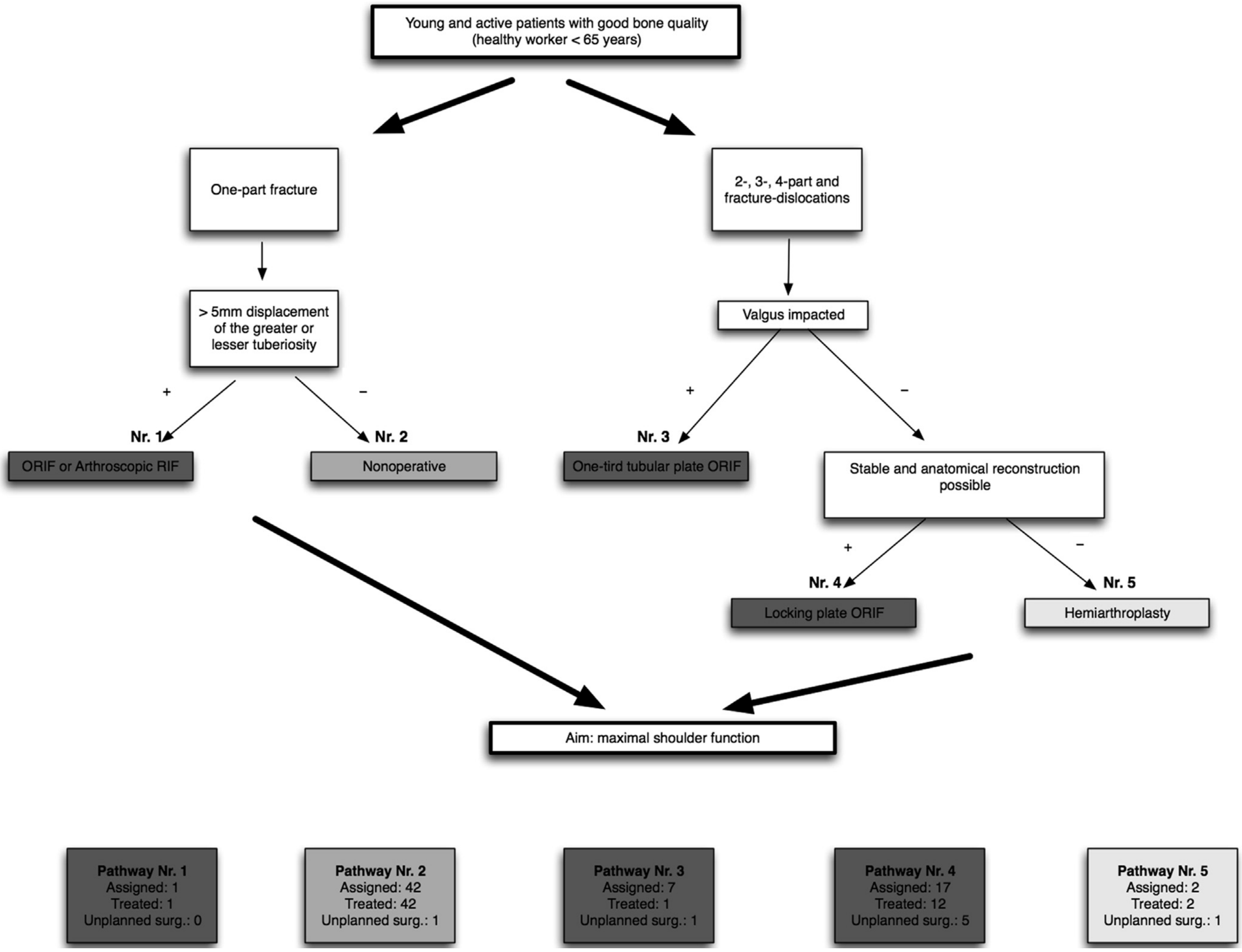

Figure 1 Treatment pathways for young patients with all pathways numbered (1-5). The total number of patients assigned and treated in each pathway is listed in the boxes (dark gray: open reduction and internal fixation [ORIF] pathways; middle gray: conservative pathways [NO]; bright gray: prosthetic replacement pathways).

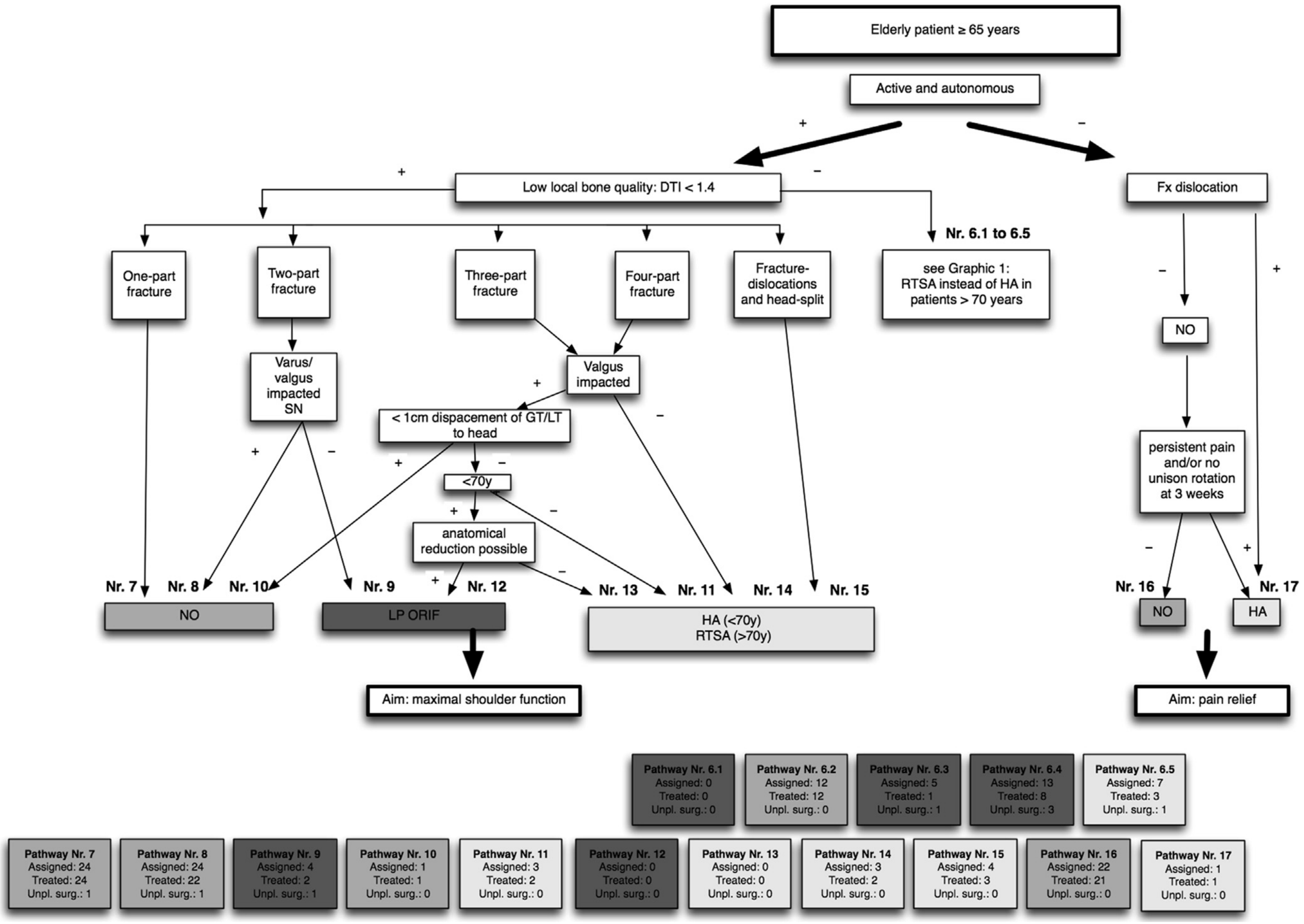

Figure 2 Treatment pathways for elderly patients with all pathways numbered (6-17). The total number of patients assigned and treated in each pathway is listed in the boxes (dark gray: open reduction and internal fixation [ORIF] pathways; middle gray: conservative pathways [NO]; bright gray: prosthetic replacement pathways). *DTI*, deltoid tuberosity index; *Fx*, fracture; *GT*, greater tuberosity; *HA*, hemiarthroplasty; *LT*, lesser tuberosity; *RTSA*, reverse total shoulder arthroplasty; *SN*, surgical neck.

function. The treatment of these elderly patients is adapted according to their local bone quality (biological age), as this is known to influence the outcome of open reduction and internal fixation (ORIF) substantially.[7,30,32,53,56] Patients with good bone quality are treated like young and active patients (Fig. 1), the only difference being that RTSA is used for patients older than 70 years instead of hemiarthroplasty (HA).[5,11,16,49,59] For patients with poor bone quality, treatment pathways depend on the fracture configuration according to the best available evidence (Fig. 2, left part).[8-10,21,27,31,38,46,51] The aim of our study was to assess the feasibility of the algorithm and prove if overall clinical outcome at 1 year justifies further clinical application.

Materials and methods

Inclusion and exclusion criteria

All patients who suffered isolated PHF between January 2014 and December 2016 were eligible for this prospective study. Exclusion criteria were age <18 years, inability (even with support) to fill out the EQ-5D questionnaire, patients refusing to take part in the study, fracture >14 days old, initial treatment elsewhere, pathologic fractures, and concomitant fractures or injuries.

Primary assessments

At initial presentation, the patients' quality of life before the trauma was assessed using the EQ-5D[36-39] and their level of independence estimated. Local bone quality (deltoid tuberosity index) (Fig. 3) and the Neer fracture type were assessed on anteroposterior (AP) and lateral radiographs. A computed tomography (CT) scan was performed if the fracture pattern was unclear or surgical treatment was planned. The consultant orthopedic surgeon in charge defined the treatment strategy according to the algorithm. All possible treatment pathways were numbered and grouped for further subgroup analysis (bottom of Figs. 1 and Figs. 2). Because the assigned and effectively chosen pathways were not always the same, both were noted for further analysis.

Figure 3 Measurement of the deltoid tuberosity index (DTI) on an anteroposterior fracture radiograph. The DTI is measured proximal to the deltoid tuberosity (✦) where the outer cortical border becomes parallel. At this level, the outer cortical diameter (a) is divided by the inner endosteal diameter (b). DTI < 1.4 correlate to low bone mineral density of the humeral head.

Follow-up assessments

Follow-up appointments were scheduled after 3 and 12 months. A specifically trained physiotherapist (M.B.) examined all patients clinically including EQ-5D, Constant scores (CS), and subject shoulder values (SSV). Radiographic examination included AP views in internal and neutral rotation as well as axial and lateral views. Any complications or unplanned surgery were noted in the protocol. Patients unable to attend the 12-month follow-up were interviewed by one of the coauthors (J.M.) by phone to assess EQ-5D and SSV.

Statistical analysis

All statistical analyses were performed with R (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org/). Descriptive statistics included means, standard deviations, ranges, and proportions. Comparative statistics included *t*-tests and χ^2 test (where appropriate Fisher's exact test was applied alternatively).

Results

General data and adherence to algorithm

A total of 192 patients could be included into this study (Fig. 4), 58 male (mean age, 58.4 years; range, 18 to 90 years) and 134 female (mean age, 69.1 years; range, 19 to 97 years). The fracture classification was based on conventional radiographs with additional CT required in 84 patients (44%). There were 85 (44%) 1-part, 75 (39%) 2-part, 15 (8%) 3-part, and 17 (9%) 4-part fractures. The mean deltoid tuberosity index was 1.53 (range, 1.22 to 2.1) in the male and 1.45 (range, 1.11 to 2.35) in the female population. In total, 132 patients were treated conservatively, 36 with ORIF and 24 with primary prosthesis (4 HA, 20 RTSA). Of all patients included, 160 (83%) were treated according to and 32 (17%) not according to the algorithm (Table I). In 9 of 32 cases (28%), the reason for deviation was not surgeon but patient related (eg, patient's decision, incompliance).

Overall outcome and outcome of treatment groups

Of the 192 patients included, 149 (78%) had a complete clinical and radiographic 1-year follow-up and another 25 (13%) were available for 1-year assessment on the telephone (Fig. 4). Finally, a total of 174 patients (91%) were available for outcome analysis. Their mean quality of life (EQ-5D) before the fracture was 0.88 (range, 0.2 to 1), and 1 year after treatment it was 0.9 (range, 0.1 to 1) ($P = .9$). The mean absolute and relative CS at the final follow-up were 72.5 points (range, 21 to 98 points) and 95% (range, 32.8% to 138.4%), respectively. The mean SSV at the final follow-up was 84.4% (range, 35% to 100%).

Patients treated conservatively according to the algorithm had significantly better functional outcomes than those treated conservatively but not following the algorithm (Table II). The same goes for patients treated with ORIF. The 4 patients treated with HA finally achieved good pain relief but limited function. Patients treated with RTSA, not according to the algorithm, showed a tendency toward better preinjury EQ-5D and better final functional outcomes (Table II).

Analysis of treatment pathways

For the subgroup analysis of each treatment pathway, only patients treated according to the algorithm with complete clinical or telephone interview at 1-year follow-up were considered (n = 143).

Young and active patients: all 1-part fractures could have been treated according to the algorithm. The one-third tubular plate ORIF for valgus-impacted fractures (pathway no. 3) was only used in 1 of 7 patients (14%), mainly because of the surgeon's preference for angular stable ORIF (Table I). Pathway no. 4 (angular stable ORIF) was correctly used in 71% (12/17 patients); the main reason for

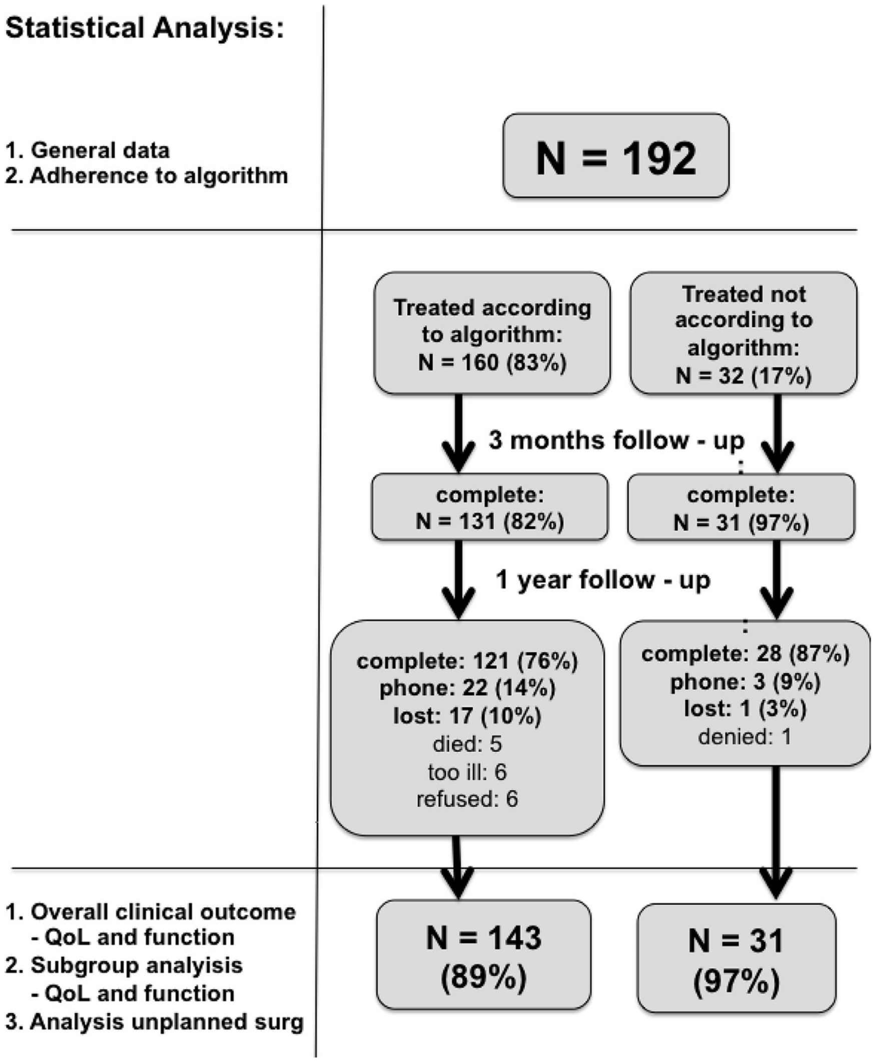

Figure 4 Flow chart with details of patient inclusions, exclusions, and follow-up. *QoL*, quality of life.

deviation was preferred conservative treatment due to patients' wish or compliance (Table I). Primary HA (pathway no. 5) was correctly performed in 2 patients.

Elderly patients: active patients with good bone quality (pathway nos. 6.1-6.5) were correctly treated in 65% (24/37). Again the pathway for conservative treatment of 1-part fractures (no. 6.2) was successful in 100% (12/12), and the one-third tubular plate (no. 6.3) was only used once (20%), mainly due to the surgeon's preference for angular stable ORIF (Table I). Angular stable ORIF (pathway no. 6.4) was used correctly in 61% (8/13), whereas the main reason for deviation from the algorithm was preferred conservative treatment for these elderly patients (Table I). The pathway for primary arthroplasty was only chosen correctly in 43% mainly due to preferred RTSA in patients between 65 and 70 years (Table I). For elderly but active patients with poor bone quality (pathways nos. 7-15), the conservative pathways (nos. 7, 8, 10) were correctly chosen in 96% (47/48). Angular stable ORIF was used twice in these patients (2/4; 50%). Primary arthroplasty pathways (nos. 11, 13, 14, 15) were used correctly in 70% (7/10) with preferred RTSA treatment as the main reason for deviation (Table I).

The conservative pathway for patients with low demands (no. 16) was correctly used in 95% (21/22). In these patients, only 1 primary arthroplasty was performed because of fracture dislocation (pathway no. 17).

Analysis of complications and unplanned surgeries

Three patients needed unplanned surgery after conservative treatment due to painful secondary displacement (Table III). The revision rate after ORIF was the highest (n = 16). Plate removal was needed in 8 cases, additional arthroscopic arthrolysis due to stiffness in another 3 patients. Early loss of reduction (n = 3), avascular necrosis (n = 1), and secondary cutout (n = 1) were further reason for revisions. Two patients with primary HA and none of the

Table I Details of the 32 patients not treated according to the algorithm

Nr	Age (yr)	Assigned pathway	Deviation surgeon related	Performed pathway	Reason for deviation from algorithm	Direction of deviation
182	78	Conservative	No	Angular stable ORIF	Patient's wish ORIF	Cons → ORIF
3	65	One-third tubular ORIF	No	Conservative	General anesthesia not possible	ORIF → cons.
5	44	Angular stable ORIF	No	Conservative	Patient's wish conservative	ORIF → cons.
14	53	Angular stable ORIF	No	Conservative	Compliance (alcohol abuse)	ORIF → cons.
93	50	Angular stable ORIF	No	Conservative	Compliance (drug abuse)	ORIF → cons.
124	46	Angular stable ORIF	No	Conservative	Compliance (alcohol abuse)	ORIF → cons.
133	59	Angular stable ORIF	No	Conservative	Patient's wish conservative	ORIF → cons.
189	65	Angular stable ORIF	No	Conservative	Patient's wish conservative	ORIF → cons.
190	93	RTSA	No	Conservative	Patient's wish conservative	Prosthetic → cons.
175	68	Conservative	Yes	Angular stable ORIF	Surgeon's decision for ORIF	Cons → ORIF
34	80	Conservative	Yes	Angular stable ORIF	Surgeon's decision for ORIF	Cons → ORIF
4	72	One-third tubular ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
12	74	One-third tubular ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
88	80	One-third tubular ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
10	69	One-third tubular ORIF	Yes	Angular stable ORIF	Surgeon's decision	ORIF → cons.
67	56	One-third tubular ORIF	Yes	Angular stable ORIF	Surgeon's decision	ORIF → cons.
73	36	One-third tubular ORIF	Yes	Angular stable ORIF	Surgeon's decision	ORIF → cons.
120	56	One-third tubular ORIF	Yes	Angular stable ORIF	Surgeon's decision	ORIF → cons.
138	49	One-third tubular ORIF	Yes	Angular stable ORIF	Surgeon's decision	ORIF → cons.
25	69	One-third tubular ORIF	Yes	RTSA	Intraoperative: full thickness cuff tear	ORIF → prosthetic
111	70	Angular stable ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
114	77	Angular stable ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
180	68	Angular stable ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
192	71	Angular stable ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
149	89	Angular stable ORIF	Yes	Conservative	Preferred conservative due to age	ORIF → cons.
51	83	Angular stable ORIF	Yes	RTSA	Intraoperative: full thickness cuff tear	ORIF → prosthetic
81	79	RTSA	Yes	Angular stable ORIF	Surgeon's decision for ORIF	Prosthetic → ORIF
13	67	HA	Yes	RTSA	Preferred RTSA despite <70 yr	Prosthetic → prosthetic
24	65	HA	Yes	RTSA	Preferred RTSA despite <70 yr	Prosthetic → prosthetic
42	65	HA	Yes	RTSA	Preferred RTSA despite <70 yr	Prosthetic → prosthetic
62	65	HA	Yes	RTSA	Preferred RTSA despite <70 yr	Prosthetic → prosthetic
171	65	HA	Yes	RTSA	Preferred RTSA despite <70 yr	Prosthetic → prosthetic

ORIF, open reduction and internal fixation; *RTSA*, reverse total shoulder arthroplasty; *HA*, hemiarthroplasty.

patients with RTSA needed revision during the study observation period. There was no significant difference in the rate of unplanned surgery between patients treated according to the algorithm and those who were not (Table II).

Discussion

To the best of our knowledge, this is the first prospective study that analyzed the adherence to protocol and outcome of a treatment algorithm for PHF. We found high adherence to the algorithm of 83%, which proves the feasibility of using it in daily clinical practice in a level 1 trauma center. Our figures of adherence to algorithm are higher than reported by LaMartina et al,[33] who found in a retrospective study 70.5% of unanimous decisions regarding operative vs. conservative treatment. The moderate use of CT scans in only 44% probably shows that uncertainty was reduced because of the use of the algorithm, and the diagnostics was not extended beyond cost-effective boundaries.

The overall clinical results and quality of life after 1 year were found to be very satisfying in all treatment groups apart from patients treated with HA.

Clinical results

Overall

Patients treated according to the algorithm regularly reached the quality of life (EQ-5D) they had before the fracture. Our mean preinjury EQ-5D values are comparable with the studies of Olerud et al.[36-38] However, with the randomization of their patients to either conservative or

Table II Outcome of all treatment groups with specific subgroup analysis of patients treated according to the algorithm compared with those who were not

Treatment group (n)	Conservative				ORIF				Hemiarthroplasty		Reverse total shoulder arthroplasty			
	All (132)	AA (116)	NAA (16)	*P* value	All (36)	AA (25)	NAA (9)	*P* value	All (4)	NAA	All (20)	AA (13)	NAA (7)	*P* value
Mean EQ-5D preoperative (pts)	0.89	0.9	0.86	.48	0.89	0.9	0.84	.3	0.89	–	0.85	0.8	1	.06
Mean EQ-5D 1 yr (pts)	0.91	0.91	0.85	.12	0.86	0.86	0.85	.7	0.79	–	0.88	0.87	0.89	.8
Mean absolute CS 1 yr (pts)	76	78.2	65.6	**<.001**	63	68.2	48.8	**.006**	44	–	69	65.6	73.7	.33
Pain	13.7	14	12.1	**.007**	12	13	9.1	**.003**	14.6	–	13.3	13.9	12.3	.3
Flexion (°)	144.7	147.2	129	**.01**	122	128	104.3	.08	70	–	134.4	120.5	157.5	.09
Mean relative CS 1 yr (%)	99.9	101.4	90.9	**.049**	81.7	90.2	64.2	**<.001**	49.8	–	97.8	93.3	105.2	.33
Mean SSV 1 yr (%)	88	89.4	82.9	.09	75	77.9	71.2	.2	45	–	82	78.3	90	.1
Unplanned surgery	3	3	0	.7	16	11	5	.5	2	–	0	0	0	

ORIF, open reduction and internal fixation; *AA*, treated according to the algorithm; *NAA*, not treated according to the algorithm; *CS*, Constant score; *SSV*, subjective shoulder value.

operative treatment, they were unable to attain these results again after 1 and 2 years. Also their 1-year functional outcome (absolute CS) was mainly lower compared with our results. In our opinion, this shows the downside of randomization of patients to either conservative or 1 operative treatment and the need for more distinct stratification. In our collective, apart from patients treated with HA, the overall functional outcome after 1 year was successful, especially if algorithm pathways were followed correctly.

Conservative treatment

Conservative treatment of 1-part fractures worked very well for young and elderly patients. Clinical results were excellent after 1 year, and unplanned surgery due to secondary displacement was rarely needed. This is in accordance with earlier studies.[31,34] Also, conservative treatment of varus- or valgus-impacted 2-part fractures in elderly patients with low bone quality (pathway no. 8) was successful. We found mainly good clinical results in these patients, which is in accordance to the studies of Court-Brown et al.[9,10] We chose conservative treatment, regardless of the fracture type (apart from fracture dislocations), for dependent low-demand patients who live in nursing homes (pathway no. 16). None of them needed unplanned surgery for pain relief. Conservative treatment needs to be specifically indicated to achieve consistently good clinical results.

Open reduction and internal fixation

We used angular stable plates for ORIF because it is the most common implant and because we have the most experience with it. However, also other implants such as intramedullary devices have been used successfully as long as the surgeon has enough experience with it.[12,61] In our algorithm, ORIF was mainly indicated for young and active patients or elderly patients with high demands and good bone quality (pathway nos. 4 and 6.4).[30,32,56] In active patients with low bone quality, the indication for ORIF was restricted to certain fracture types that are specifically amenable to ORIF (2-part or valgus-impacted fractures, pathway nos. 9 and 12).[27,38] However, the relevance of those pathways is reduced as they were hardly ever assigned. The algorithm may be simplified for 3- and 4-part fractures as the pathway nos.10-13 have hardly been used. In young patients and in elderly patients with good bone quality and displaced valgus-impacted fractures, we considered the theoretical advantages of a low-profile one-third tubular plate (pathway nos. 3 and 6.3).[3,24] However, this option was hardly used because most of the surgeons preferred a locking plate. Thus the one-third tubular plate will be omitted in a future version of the algorithm. With our consistent selection of patients for ORIF, we achieved very satisfying clinical results after 1 year, especially if the treatment was according to the algorithm. Compared with other studies, we had fewer severe complications like avascular necrosis or head screw cutouts,[55,57] which may be

Table III Details of all patients who needed unplanned surgery

Chosen treatment pathway	Total patients	Treatment according to algorithm	Unplanned surgery	Time to revision after primary fracture treatment
Conservative				
2	1	Yes	ORIF due to secondary displacement of GT	2 mo p.o.
7	1	Yes	RTSA due to secondary displacement	1 mo p.o.
8	1	Yes	ORIF due to secondary displacement	1 mo p.o.
ORIF				
3 (one-third tubular plate)	1	Yes	AA and RI due to stiffness	9 mo p.o.
4 (angular stable)	8	4 yes 2 no	6 × RI	6 × 12 mo p.o.
		1 yes	1 × AA and RI due to stiffness	10 mo p.o.
		1 no	1 × revision to HA due to AVN	14 mo p.o.
6.3 (one-third tubular plate)	1	Yes	AA and RI due to stiffness	12 mo p.o.
6.4 (angular stable)	3	Yes	2 × RI	2 × 12 mo p.o.
			1 × revision to RTSA due to loss of reduction	1 mo p.o.
9 (angular stable)	3	No	1 × revision ORIF due to loss of reduction	1 mo p.o.
		Yes		1 mo p.o.
		No	1 × Revision RTSA due to loss of reduction	3 mo p.o.
			1 × AA and partial RI due to cutout	
Prosthesis				
5 HA	1	Yes	AA due to stiffness	14 mo p.o.
6.5 HA	1	Yes	1. Removal of HA due to infection	2 moh p.o.
				4 mo p.o.
			2. Revision RTSA	6 mo p.o.
			3. ORIF humerus due to periprosthetic fracture	

ORIF, open reduction and internal fixation; *GT*, greater tuberosity; *p.o.*, postoperative; *RTSA*, reverse total shoulder arthroplasty; *AA*, arthroscopic arthrolysis; *RI*, removal of implant; *HA*, hemiarthroplasty; *AVN*, avascular necrosis.

the result of our very specific patient selection. However, the rate of unplanned surgery was higher compared with other studies[40,41,57,58] with a high rate of implant removal in our collective. This may partially be explained by the more prominent implant we used compared with most other studies.[41,55,58] A further explanation for the higher revision rate might be that several surgeons with different levels of experience in shoulder surgery performed ORIF. As a direct consequence of this relatively high revision rate, we changed the implant to a less prominent one. According to Saltzman et al,[47] bone grafting may be a viable option to further improve the outcome of the patients treated with ORIF as well.

Hemiarthroplasty

We considered HA for our young patients if the fracture could not be reduced in a stable manner and there was an intact rotator cuff (a rupture would trigger the change to RTSA). This occurred twice and resulted in limited functional outcomes. Another 2 patients between 65 and 70 were treated with HA and they clearly had restricted function as well. Overall, HA was only good for pain relief and led to limited function in our patients, which reflects the findings of a recent study with the same implant.[60]

Reverse total shoulder arthroplasty

RTSA is becoming the mainstay of treatment for displaced PHF in the elderly[21,28,49] with clearly better results than HA.[16,49,59] Our patients also had very satisfying functional outcomes after 1 year without requiring revision surgery. Although the age limit was set at 70 years, we found that most of the patients between 65 and 70, previously considered for HA, were instead treated with RTSA. Interestingly, these patients had a better preinjury quality of life and tended to have better functional outcomes after 1 year. Apparently, these patients were very active and the surgeons wanted to offer them the best possible solution, which was RSTA rather than HA. The age cut off for RTSA is still under debate with the increasing tendency to lower it as long-term RTSA data (not for treating fractures) are promising[2] and the results after HA consistently unpredictable.[60]

Future improvements of the algorithm

First, the one-third tubular plate option will be omitted as this technique has hardly been used. Secondly, to lower the implant removal rate, we will change to a low-profile locking plate. Finally, because RTSA was preferred to HA in patients older than 65 years and younger than 70 years, and we experienced very limited outcomes after HA, the age limit for RTSA will be reduced to ≥65 years.

Limitations

The design of this study is incomparable with other studies, as it is the first study that prospectively follows and tests an algorithm for treating fractures. It is stratification instead of a randomization, because patients are specifically assigned to a certain pathway. Instead of searching for further fragmented evidence, we constructed a framework to apply evidence already published; we investigated performance and feasibility, including adherence to protocol in daily practice. A study design with a control group treated without algorithm would have strengthened our data, but this could not be performed in a single institution.

A disadvantage of sophisticated treatment pathways like those in this study naturally results in a high number of treatment options with only small numbers in some of them. This limits a thorough statistical subgroup analysis. However, different pathways have already been studied relative to each other in published series, and were in our algorithm as premises. Our study offers the synthesis to overall performance and not fragmented knowledge. Furthermore, it was not the aim of this study to assess the clinical outcome of the specific subgroups. As a first step, it was the aim of this study to validate the use of such an algorithm in a teaching hospital like ours. In the near future, we will hopefully have more data to perform further analysis of the specific treatment pathways.

A further limitation is that several surgeons with varying experience in shoulder surgery were involved in the ORIF treatment, which could partly explain the high rate of unplanned surgery in this treatment group. However, in our opinion, this reflects realistic circumstances in a level 1 trauma and teaching hospital.

Conclusion

This comprehensive algorithm is designed as a non-compulsory treatment guideline for PHF, which prioritize patients' demands and biology. The high adherence proves that it is a helpful tool for decision making. Furthermore, this algorithm leads to very satisfying overall results with low complication and revision rates.

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