Summary of neuraminidase (NA) amino acid substitutions assessed for their effects on inhibition by neuraminidase inhibitors (NAIs).

Type/subtype *Comments*	Amino acid substitution[a]	N2 numbering[b]	Susceptibility assessed by NA inhibition assays (IC_{50} fold change)[c]				Source of viruses/ selection with[d]	References
			Oseltamivir	Zanamivir	Peramivir	Laninamivir		
Type A								
A(H1N1)pdm09	S110F	110	NI/**RI** (9.8–**10.5**)	**RI (17–18)**	?[e]	?	Sur	(1, 2)
	I117R	117	NI (1)	**RI (10)**	?	?	Sur	(3)
	E119A	119	NI/**RI** (8–**17**)	**RI (58–90)**	NI/**RI** (7–**12**)	**RI (82)**	RG	(4, 5)
	E119D	119	**RI (25–94)**	**HRI (583–2731)**	**HRI (104–402)**	**HRI (649–702)**	Clin/Zan; RG	(5-7)
	E119G	119	NI (1–7)	**HRI (113–1306)**	**RI/HRI (51–167)**	**HRI (112–327)**	RG; Clin/Zan	(5, 7-9)
	E119V	119	**RI (60)**	**HRI (571)**	**RI (25)**	?	RG	(8)
Cell culture-selected	Q136K	136	NI (1)	**HRI (86–749)**	**HRI (143)**	**RI (42–45)**	Sur; RG; in vitro	(4, 10, 11)
Cell culture-selected	Q136R	136	NI (1)	**HRI (200)**	**HRI (234)**	**RI (33)**	Sur	(12)
	R152K	152	**RI (18–43)**	NI/**RI** (4–**12**)	NI (4–7)	**RI (16)**	RG	(5, 7)
	D199E	198	**RI (16–26)**	NI (7–8)	NI (3)	NI (3)	Sur; RG	(7, 13)
	D199G	198	**RI (17)**	NI (6)	NI (2)	NI (2)	Sur; in vitro; RG	(4, 8)
	D199Y	198	**RI (37)**	**RI (28)**	NI (4)	NI (7)	Clin/Sur	(14)
	I223K	222	**RI (12–39)**	NI (5–6)	NI (1–4)	NI (4)	Clin/Sur; RG	(13, 15, 16)
	I223L	222	**RI (11)**	NI (2)	NI (1)	NI (1)	Clin/Sur	(17)
	I223M	222	**RI (12)**	NI (2)	NI (2)	NI (1)	Clin/Sur	(17)
	I223R	222	**RI (13–58)**	NI/**RI** (8–**12**)	NI/**RI** (5–**11**)	NI (2–5)	Clin/No; Clin/Ose/Zan; RG; Clin/Sur	(13, 15, 17-21)
	I223T	222	NI/**RI** (9–**15**)	NI (3)	NI (2)	NI (2)	Clin/Sur	(13)
	I223V	222	NI (3–6)	NI (1–2)	NI (1–2)	NI (1)	RG; Clin/Sur	(4, 8, 22)
	S247G	246	**RI (15)**	NI (1)	NI (1)	NI (1)	Clin/Sur	(13)
	S247N	246	NI (4–8)	NI (2–5)	NI (1–3)	NI (3)	Clin/Sur	(22, 23)
	S247R	246	**RI (36–37)**	**RI (51–54)**	**RI/HRI (94–115)**	**RI/HRI (90–122)**	Clin/No	(3)
	H275Y	**274**	**HRI (221–1637)**	NI (1–6)	**RI/HRI (50–751)**	NI (1–2)	Clin/Ose; Clin/Sur; in vitro	(24-33)
	R293K	292	**RI (33)**	NI (4)	NI (8)	?	RG	(5, 9)
	N295S	294	**RI/HRI (64–208)**	NI (2–9)	NI/**RI** (3–**12**)	NI (3)	RG	(4, 5, 8, 12)
	I427T	427	**RI (37)**	**RI (41)**	NI (6)	**RI (11)**	Sur	(14)
	I436N	436	**RI (31)**	**RI (71)**	**RI (20)**	**RI (19)**	RG	(34)

	P458T	459	**HRI (280)**	**HRI (808)**	**HRI (148)**	**HRI (211)**	RG	(7)
	H275Y+I436N	274+436	**HRI (4811)**	**RI (36)**	**HRI (10460)**	**RI (22)**	RG	(34)
Some IC_{50}s were given for mixed virus populations; to be assessed using recombinant NA	D199N+H275Y	198+274	**HRI (318–744)**	NI (2–3)	**HRI (108)**	?	Sur; Clin/Ose	(31, 35)
	G147R+H275Y	147+274	**HRI (2649)**	NI (5)	**HRI (1427)**	NI (1)	Clin/Lan+Per	(3)
	E119A+H275Y	119+274	**HRI (1173)**	**RI (56)**	NI (3)	?	RG	(5)
	E119D+H275Y	119+274	**HRI (790–3381)**	**HRI (136–903)**	**HRI (5958–33333)**	**HRI (366)**	RG	(5, 6)
	E119G+H275Y	119+274	**HRI (225–2483)**	**HRI (225–1546)**	**HRI (3333–93433)**	**HRI (650)**	Clin/ Zan; Sur; RG	(5, 9)
	I223V+S247N	222+246	**RI (11–16)**	NI (3)	NI (4)	NI (3)	Clin/Sur	(22, 36)
	I223K+H275Y	222+274	**HRI (>10822)**	**RI (11)**	**HRI (5343)**	**RI (11)**	Sur; in vitro	(27)
	I223R+H275Y	222+274	**HRI (>9100)**	**RI (22–27)**	**HRI (>7500)**	**RI (17)**	Clin/Ose; RG	(16, 20, 27)
	I223V+H275Y	222+274	**HRI (1733)**	NI (2)	**HRI (1331)**	?	Clin/Ose; RG	(8, 37)
	S247N+H275Y	246+274	**HRI (5880)**	NI (5)	**HRI (334)**	?	Sur	(23)
	Q313R+I427T	313+427	**RI (10–43)**	NI/**RI (3–20)**	NI (4)	?	Sur	(25, 38)
A(H1N1)	E119V	119	**RI/HRI (15–1727)**	**HRI (136–2144)**	**HRI (5050)**	?	RG	(39, 40)
Host cell selected in both studies; not found in clinical specimens	Q136K	136	NI (1)	**RI/HRI (36–327)**	**RI (75–80)**	?	Sur	(25, 41)
This result is virus specific	Y155H	155	**HRI (123)**	**HRI (555)**	?	?	Sur	(42)
	I223M	222	NI (8)	NI (1)	NI (1)	?	RG; in vitro/Zan	(43)
	I223V	222	NI (3)	NI (2)	NI (1)	?	RG; in vitro/Zan	(43)
	S247G	246	NI (5)	NI (1)	?	?	Sur	(44)
	H275Y	**274**	**HRI (321–2597)**	NI (1–2)	**HRI (111–1095)**	?	Sur; RG	(25, 40, 44, 45)
	R293K	292	NI (1)	**RI (18)**	?	?	RG	(40)
	N295S	294	**RI/HRI (40–197)**	NI (1–5)	**RI (12)**	?	RG	(39, 40)
	I117V+E119V	117+119	NI (7)	**HRI (391)**	?	?	RG	(40)
	I117M+E119V	117+119	**RI (20)**	**HRI (181)**	?	?	RG	(40)
	I117V+H275Y	117+274	**HRI (683)**	NI (1)	?	?	RG	(40)
	I117M+H275Y	117+274	**HRI (395)**	NI (1)	?	?	RG	(40)
	I117V+N295S	117+294	**RI (60)**	NI (1)	?	?	RG	(40)

	I117M+N295S	117+294	**RI (52)**	NI (4)	?	?	RG	(40)
	E119V+H275Y	119+274	**RI (21)**	**HRI (132)**	?	?	RG	(40)
Both changes were host cell selected	Q136K+D151E	136+151	NI (1)	**RI (25)**	**RI (18)**	?	Sur	(25)
Q136K was host cell selected	Q136K+H275Y	136+274	**HRI (198)**	**RI (15)**	**HRI (1805)**	?	Sur	(25)
D151E/N was host cell selected	D151E/N+H275Y	151+274	**HRI (231–799)**	NI (1–3)	**RI/HRI (80–718)**	?	Sur	(25)
D151G was host cell selected	D151G+H275Y	151+274	**HRI (1189)**	**RI (14)**	**HRI (1161)**	?	Sur	(25)
	I223M+H275Y	222+274	**HRI (1943)**	NI (1)	**HRI (400)**	?	RG; in vitro/Zan	(43)
	I223V+H275Y	222+274	**HRI (584–971)**	NI (1–2)	**HRI (893)**	?	RG; in vitro/Zan	(40, 43)
	I223V+N295S	222+294	**RI (97)**	NI (2)	?	?	RG	(40)
	R293K+H275Y	292+274	**HRI (207)**	NI (1)	?	?	RG	(40)
	N295S+H275Y	294+274	**HRI (108)**	NI (1)	?	?	RG	(40)
	S334N+H275Y	336+274	**HRI (415)**	NI (1)	?	?	RG	(40)
	I117V+N295S+H275Y	117+294+274	**HRI (336)**	**RI (12)**	?	?	RG	(40)
	I117M+N295S+H275Y	117+294+274	**HRI (121)**	**RI (11)**	?	?	RG	(40)
Q136K+D151N were host cell selected	Q136K+D151N+H275Y	136+151+274	**HRI (356)**	NI (4)	**HRI (2300)**	?	Sur	(25)
	I223V+N295S+H275Y	222+294+274	**HRI (300)**	**RI (13)**	?	?	RG	(40)
A(H5N1)	V96A	116	**RI (11–18)**	**RI (10–63)**	NI (4)	?	Sur	(46, 47)
	I97T	117	**RI (19)**	**RI (12)**	?	?	Sur	(48)
	I117T[f]	117	NI (1)	NI (1)	NI (1)	NI (1)	Sur	(49)
	I97V	117	NI (5–9)	NI (2–4)	?	?	RG; Sur	(48, 50, 51)
	E99A	119	**RI (10–35)**	**HRI (51–1254)**	NI (7)	?	RG	(5, 50)
	E99D	119	**RI (87)**	**HRI (132)**	**HRI (1436)**	?	RG	(5)
	E99G	119	NI (3–6)	**HRI (438–1485)**	**RI/HRI (12–164)**	?	RG; in vitro/Zan	(5, 43)
	Q116L	136	**RI (26)**	**HRI (350)**	?	?	In vivo/Zan	(52)
	V129A	149	NI (4)	NI (8)	?	?	Sur	(53)
	D179G	198	**RI (32)**	**RI (44)**	NI (4)	?	RG; in vitro/Zan	(43)
	I203M	222	**RI (36)**	NI (1)	NI (1)	?	RG; in vitro/Zan	(43)
	I203V	222	NI (7)	NI (1)	NI (1)	?	RG; in vitro/Zan	(43)
	S227N	246	**RI (24)**	NI (2)	?	?	Sur	(46)

	S247N[f]	246	NI (6)	NI (1)	NI (4)	NI (2)	Sur	(49)
	H255Y	**274**	**RI/HRI (44–2502)**	NI (1–3)	**RI/HRI (23–533)**	NI (6)	Sur; Clin/Ose; RG; in vitro/Zan	(5, 43, 50, 54, 55)
	N275S	294	**RI/HRI (12–138)**	NI/**RI** (1–**27**)	NI/**RI/HRI** (1–**130**)	?	Clin/Ose; RG	(5, 49, 50, 54, 56)
	N295D[f]	294	NI (1)	NI (4)	NI (2)	NI (2)	Sur	(49)
	N295S[f]	294	**RI (14)**	NI (4)	NI (6)	NI (3)	Sur	(49)
	K412T	432	NI (9)	**RI (12)**	NI (5)	?	Sur; in vitro	(57)
	T438I[f]	439	NI (1–8)	**RI/HRI (17–98)**	NI/**RI** (6–**23**)	?	RG, Sur	(58)
	T438N[f]	439	NI (2)	**RI (12)**	NI (2)	NI (2)	Sur	(49)
	I97V+I294V	117+314	**RI (16)**	NI (1)	NI (1)	?	Sur	(47)
	E99A+H255Y	119+274	**HRI (1530)**	**RI (50)**	**HRI (2686)**	?	RG	(5)
	E99D+H255Y	119+274	**HRI (160)**	**RI (65)**	**HRI (1629)**	?	RG	(5)
	E99G+H255Y	119+274	**HRI (801)**	**RI (76)**	**HRI (>7692)**	?	RG	(5)
	I203L+ S227N	222+246	**RI (14)**	NI (1)	NI (5)	?	Sur; in vitro	(57)
	I203M+H255Y	222+274	**HRI (8024)**	NI (3)	**HRI (3340)**	?	RG; in vitro/Zan	(43)
	I203V+H255Y	222+274	**HRI (1925)**	NI (2)	**HRI (2106)**	?	RG; in vitro/Zan	(43)
	N295S+T438N[f]	294+439	**HRI (51–74)**	**HRI (76–86)**	**HRI (73–90)**	**RI (16–19)**	Clin/Sur	(49)
	K130N+I203L+S227N	150+222+246	**RI (77)**	NI (1)	?	?	Sur	(46)
A(H3N2)	E119D	119	NI (2)	**RI (32)**	NI (2)	?	RG	(59)
	E119I	119	**HRI (208)**	**RI (17)**	NI (3)	?	Clin/Ose; in vitro	(60)
	E119V	119	**RI/HRI (18–2057)**	NI (1–7)	NI (1–3)	NI (3–4)	Sur; Clin/Ose; in vitro; RG	(39, 45, 59-64)
Host cell selected, not found in clinical specimens	Q136K	136	NI (1–7)	**RI**/**HRI** (11–132)	NI (3–9)	NI (2)	Sur	(21, 33, 65)
	N142S	142	**HRI (595)**	**HRI (244)**	**RI (40)**	**RI (53)**	Clin/Sur	(21)
Cell culture-selected	D151A	151	NI (2–3)	**RI (29–43)**	**RI (10)**	NI (7)	Sur	(21, 44)
Cell culture-selected	D151E	151	**RI (11)**	NI (2)	?	?	RG	(66)
Cell culture-selected	D151G	151	NI (1)	**HRI (>1500)**	?	?	RG	(67)
	I222L	222	NI (9)	NI (2)	?	?	RG	(68)
	R224K	224	**HRI (>4000)**	**RI (>50)**	?	?	RG	(66)
	N245Y	245	**RI (15)**	NI (5)	NI (2)	NI (1)	Sur	(17)
	Del 245–248[g]	245–248	**HRI (157–222)**	NI/**RI (3–21)**	NI (1)	NI (1)	Clin/Ose	(69, 70)

	Del 247-250[g]	247-250	**HRI (235)**	**RI (17)**	NI (5)	NI (1)	Sur/recNA	(70)
	K249E	249	**RI (10–15)**	NI (4–6)	NI (1–3)	NI (1–3)	Sur	(3)
	E276D	276	**RI (15)**	**HRI (160)**	?	?	RG	(66)
	R292K	292	**HRI (>10 000)**	NI/**RI/HRI (3–134)**	**RI/HRI (14–719)**	NI (2–3)	Clin/Ose, Clin/Ose+Per; in vitro/Zan; RG; Clin/Sur	(12, 21, 39, 44, 59, 61, 66, 71-73)
	N294S	294	**HRI (300–1879)**	NI (8)	NI (1)	?	Clin/Ose; RG	(39, 73)
Increased NA K_ms for MUNANA substrate[h]	N329K[i]	329	NI/**RI (5–21)**	NI/**RI (3–12)**	?	?	Sur	(13, 74, 75)
Increased NA K_ms for MUNANA substrate[h]	N329R[i]	329	**RI (13)**	NI (8)	?	?	Sur	(75)
Increased NA K_ms for MUNANA substrate[h]	S331R[i]	331	NI/**RI (5–77)**	NI/**RI (3–30)**	?	?	Sur	(13, 74, 75)
Increased NA K_ms for MUNANA substrate[h]	S334R	334	NI (<2)[j]	NI (<2)[j]	?	?	Sur	(75)
	R371K	371	**RI (45)**	**RI (15)**	?	?	RG	(66)
T148I was host cell selected	E119V+T148I	119+148	**HRI (>6000)**	**HRI (>800)**	**HRI (>110)**	**HRI (>250)**	Sur; in vitro; RG	(64)
	E119V+I222L	119+222	**HRI (1571)**	NI (5)	?	?	RG	(68)
	E119V+I222V	119+222	**HRI (293–2286)**	NI (2)	NI (7)	?	Clin/Ose	(63, 76)
	I222T+S331R	222+331	**RI (12–31)**	NI (3–7)	NI (2)	NI (3–4)	Sur/Clin	(21)
	Q391K+K249E	391+249	**RI (87)**	**RI (32)**	**RI (16)**	NI (9)	Sur	(3)
A(H3N2)v	S245N	245	NI (1)	NI (1)	NI (1)	NI (1)	Sur; RG	(77)
	S247P	247	**RI (42)**	**HRI (266)**	NI (2)	NI (9)	Sur; RG	(77)
	S245N+S247P	245+247	**RI (31–40)**	**HI/HRI (66–235)**	NI (1–2)	NI (7–9)	Sur; RG	(33, 77)
A(H7N9)	E115A	119	**RI (19)**	**HRI (228)**	**RI (20)**	**RI (62)**	In vitro; recNA	(78)
	E115D	119	**RI (14)**	**HRI (1436)**	**HRI (411)**	**HRI (383)**	In vitro; recNA	(78)
	E115G	119	NI (2)	**HRI (419)**	**RI (48)**	**HRI (124)**	In vitro; recNA	(78)
	E115V	119	**RI/HRI (84−169)**	NI (6−9)	NI (1−2)	NI (2−5)	Sur; P-p; in vitro; recNA; RG	(78-80)
	Q132K	136	NI (1)	**HRI (702)**	**HRI (131)**	**HRI (313)**	In vitro; recNA	(78)
	R148K	152	NI (1)	NI (5)	NI (3)	**RI (16)**	In vitro; recNA	(78)

	I219K	222	**RI (32–46)**	NI/**RI (8–17)**	NI/**RI (6–11)**	**RI (13–27)**	In vitro; recNA; Sur; P-p	(78, 79)
	I219L	222	NI (5)	NI (2)	NI (1)	NI (2)	RG	(80)
	I219R	222	**RI (37–143)**	**RI (12–38)**	**RI (12–44)**	**RI (14–63)**	In vitro; recNA; Sur; P-p	(78, 79)
	T244P	247	**RI (27)**	**RI (69)**	NI (4)	NI (9)	In vitro; recNA	(78)
	H271Y	274	**HRI (105)**	NI (2)	NI (9)	NI (2)	In vitro; Sur	(78)
	E273D	276	**RI (13)**	**HRI (427)**	**RI (25)**	**RI (90)**	In vitro; recNA	(78)
	R289K	292	**HRI (>4600)**	**RI/HRI (11–67)**	**HRI (405–2487)**	**RI (16–35)**	In vitro; recNA; Sur; P-p	(78, 79, 81, 82)
	N291S	294	NI (2)	**RI (10)**	NI (1)	NI (3)	In vitro; recNA	(78)
	R367K	371	**RI (70)**	**RI (64)**	**RI (29)**	**RI (19)**	In vitro; recNA	(78)
	E115V+I219L	119+222	**HRI (306)**	NI (8)	NI (2)	NI (4)	RG	(80)
Type B								
Not found in clinical specimen	H101L	103	NI (2–3)	**RI (30–34)**	**HRI (688–791)**	NI/**RI (4–5)**	Sur; RG	(83)
	G104E	106	**HRI (87)**	**HRI (1220)**	**HRI (17724)**	**HRI (701)**	Sur	(3)
	E105K	107	NI/**RI (4–10)**	NI/**RI (1–42)**	**RI/HRI (6–681)**	NI/**RI (1–12)**	Clin/No; RG	(84, 85)
	G108E	110	NI/**RI/HRI (4.9–215)**	NI/**RI/HRI (4.9–4493)**	**HRI (55)**	NI /**HRI (3–7310)**	Sur; Clin/Ose; RG	(83)
	E117A	119	**HRI (>300-3171)**	**HRI (>560–12538)**	**HRI (>1598–13780)**	**HRI (421–2163)**	Sur; RG	(85-88)
	E117D	119	**HRI (>300)**	**HRI (>560)**	**HRI (>1598)**	?	RG	(86)
	E117G	119	**RI/HRI (6–53)**	**RI/HRI (33–4612)**	**HRI (>1598–>10000)**	**HRI (423–855)**	In vitro; RG	(85, 86, 89)
	E117V	119	**HRI (300)**	NI (2)	**HRI (531)**	?	RG	(86)
	H134N	136	NI (3–4)	**HRI (121–212)**	**HRI (100–131)**	**RI/HRI (49–240)**	Sur; Clin/No; RG	(3, 90, 91)
	H134Q	136	NI (3)	**RI (6)**	?	?	Sur	(1)
	H134Y	136	NI (4)	NI (1)	**HRI (76)**	NI (2)	Sur	(3)
	Q138R	140	NI (1)	**RI (15)**	**RI (41)**	**RI (7)**	Sur; in vitro	(92)
	P139S	141	**RI/HRI (10–68)**	NI/**RI/HRI (2–160)**	**RI/HRI (12–>9091)**	NI/**RI/HRI (3–142)**	Sur; in vitro; RG	(85, 92)
	G140R	142	**RI/HRI (9–184)**	NI/**RI/HRI (1–1037)**	**RI/HRI (12–9091)**	NI/**RI/HRI (2–1197)**	Sur; in vitro; RG	(85, 92)
	Y142H	144	NI (2)	NI (1)	**RI (6)**	NI (1)	Sur	(12)
	G145E	147	NI (1)	NI (1)	**RI (14)**	NI (1)	Sur	(21)
	G145R	147	NI (2–3)	NI/**RI (3–9)**	**RI (5–6)**	NI (1–3)	Sur	(17)
Not found in clinical specimen	T146I	148	NI (2)	NI (1)	**HRI (145)**	NI (1)	Sur	(21)

Not found in clinical specimen	T146K	148	NI/**RI (1–34)**	NI/**RI/HRI (3–192)**	**HRI (187–21893)**	NI/**RI (1–6)**	Sur; RG	(83)
Not found in clinical specimen	T146P	148	NI/**RI (2–8)**	NI/**RI (4–11)**	**HRI (128–3338)**	NI (3)	Sur; RG	(83)
	R150K	152	**HRI (60–252)**	NI/**RI/HRI (5–1000)**	**HRI (214–2869)**	**HRI (473)**	Clin; Clin/Zan; RG; Sur	(2, 45, 66, 86, 91, 93-95)
	N151S	153	NI (1)	**RI (7)**	?	?	Sur	(13)
	K152M	154	**RI (5.4)**	NI (1)	NI (1)	NI (1)	Sur	(21)
	K152N	154	**RI (6)**	NI (2)	NI (1)	NI (2)	Sur	(3)
	N169S	170	NI (2)	NI (1)	NI (1)	NI (1)	RG	(83)
	D197E	198	**RI (12–26)**	NI (3–7)	**RI (16–18)**	?	Clin/No; Sur; RG	(42, 88, 96)
Not found in clinical specimen	D197G	198	NI (3)	**RI (5.4)**	?	?	Sur	(21)
	D197N	198	NI/**RI (4–10)**	NI/**RI (3–17)**	**RI (5.4–24)**	NI (2–3)	Clin/No; Clin/Ose; Sur	(3, 44, 45, 62, 97)
	D197Y	198	**RI/HRI (15/57)**	**RI (14)**	**HRI (168)**	?	Sur; RG	(88, 98)
	A200T	201	**RI (6–48)**	NI/**RI (3–23)**	**RI (67–85)**	NI/**RI (4–27)**	Sur; RG	(14, 33, 83)
	I221L	222	**HRI (70–121)**	**RI (7–41)**	**RI (39–56)**	?	Clin/Ose	(99, 100)
	I221N	222	**RI/HRI (36–219)**	**RI (6–14)**	**HRI (136–956)**	?	RG	(100)
	I221T	222	**RI (5–18)**	NI (2–4)	**RI (15–43)**	NI (<3)	Clin/No; Sur; RG	(29, 42, 88, 97, 101, 102)
	I221V	222	NI (2)	NI (2)	**RI (6)**	NI (3)	Sur	(3)
	G243D	244	**RI (23)**	**HRI (257)**	?	?	Sur	(17)
	G243S	244	**RI (19)**	**RI (22)**	**HRI (58)**	NI (3)	Clin/Sur	(17)
	A245G	246	NI (2)	NI (1)	**RI (18)**	NI (0–1)	Sur	Unpublished
	A245T	246	**RI (9–24)**	**RI/HRI (39–205)**	**RI (5–10)**	NI/**RI (3–5)**	Sur	(14, 29)
	S246P	247	NI (2)	**RI (40)**	?	?	Sur	(2)
	G247D	248	NI (4)	NI (4)	NI (2)	NI (2)	RG	(83)
	H273Y	274	NI/**RI (2–12)**	NI (1)	**RI/HRI (15–13434)**	NI (1)	Sur; RG	(3, 31, 44, 88)
	R292K	292	**HRI (>300)**	**RI (29)**	**HRI (502)**	?	RG	(86)
	N294S	294	**RI (8–61)**	NI/**RI (1–18)**	**RI (17–58)**	?	Clin/No; RG	(88, 91, 100, 103)
	K360E[i]	358–359[k]	NI (2)	NI (2)	**HRI (165)**	NI (<3)	Sur	(29)
	I361V	358	NI (2)	NI (1)	NI (1)	NI (1)	RG	(83)
	R374K	371	**HRI (101–407)**	**RI/HRI (29–145)**	**HRI (352)**	?	Sur; RG	(44, 88)
	A395E	392	**RI (5)**	NI (1)	**RI (5.5)**	NI (<3)	Sur	(29)
	L396H	393	NI (3)	**RI (11)**	?	?	Sur	(14)
	G407S	404	NI (4)	**RI (7)**	?	?	Clin/Ose; Sur	(97)

	D432G	429	NI (1)	NI (1–3)	**RI/HRI (41–148)**	NI (1–3)	Sur; RG	(29, 83)
	D432N	429	NI (1)	NI (1)	**RI (8)**	NI (1)	Sur	(14)
	H439P	439	NI/**RI (1–6)**	NI/**RI (4–13)**	**HRI (56–120)**	NI (2-4)	Sur; RG	(83)
	H439R	439	NI (1)	**RI (5 –10)**	**RI (20–23)**	NI (2)	Sur; RG	(83)
	M464T	464	NI (1)	NI (1)	**RI (8)**	NI (1)	Sur	(14)
	T106I+P165L	108+166	NI (4)	**RI (14)**	?	?	Sur	(3)
	G140R+N144K	142+146	NI (6)	**RI (10)**	**HRI (257)**	?	Sur	(31)
	Y142H+G145R	144+147	NI (?)	NI (?)	**HRI (487)**	NI (<3)	Sur	(29)
	T146P+N169S	148+170	**RI (31–44)**	**HRI (225–573)**	**HRI (7158–10074)**	**HRI (86–280)**	Sur; RG	(83)
	K186R+I262T	187+263	NI (3)	**RI (17)**	?	?	Sur	(3)
	G247D+I361V	248+358	NI/**RI (2–6)**	NI/**RI (3–6)**	NI/**RI (4–46)**	NI (1–3)	Sur;RG	(83)

[a] Numbering is based on the neuraminidase subtype for type A viruses and the neuraminidase of type B viruses.
[b] Equivalent N2 numbering is based on an alignment of neuraminidases from A/Brisbane/59/2007 [H1N1], A/California/7/2009 [H1N1pdm09], A/turkey/Turkey/1/2005 [H5N1], A/Singapore/1/57 [H2N2], A/Aichi/2/68 [H3N2], A/Perth/16/2009 [H3N2], A/Hong Kong/1074/97 [H9N2], A/Anhui/1/2013 [H7N9], B/Brisbane/60/2008 [B/Vic lineage], B/Bangladesh/3333/2007 [B/Yam lineage].
[c] Assessed by NA inhibition (NI) assays: chemiluminescent (NA-Star), fluorescent (MUNANA) and/or colorimetric (fetuin). NAI phenotype is shown according to the referenced studies: NI, normal inhibition; **RI**, reduced inhibition; **HRI**, highly reduced inhibition as defined in (104). Fold-changes in IC_{50} (half maximal inhibitory concentration) relative to wild-type virus or type/subtype-specific median IC_{50}s, are shown in parentheses. For type A viruses: <10-fold - NI; 10-100-fold - RI; >100-fold - HRI. For type B viruses: <5-fold - NI; 5-50-fold - RI; >50-fold - HRI (102).
[d] Clin, clinical detection; No, no NAI used; Ose, oseltamivir used; Zan, zanamivir used; P-p, Plaque purification; RG, reverse genetics; recNA: Recombinant NA; Sur, Surveillance studies; Lan, laninamivir used; Per, peramivir used. The most common amino acid substitutions associated with **HRI** by oseltamivir and peramivir which have been associated with clinical resistance are shown in bold text.
[e] ? signifies that the NAI(s) indicated were not studied.
[f] Equivalent N1 numbering is based on an alignment of neuraminidase from A/bald eagle/Florida/W22-134-OP/2022 (H5N1) clade 2.3.4.4b influenza virus that does not carry a 20 amino acid deletion in the neuraminidase stalk region.
[g] Del signifies deletion of the amino acids indicated.
[h] The positive charge on the amino acid sidechain causes higher NA K_ms for the MUNANA substrate resulting in higher IC_{50} values and therefore fold-changes relative to wild-type virus or type/subtype-specific median IC_{50}s.
[i] Shows NI in current NA background.
[j] Some viruses lacked sufficient neuraminidase activity to allow IC_{50} determination.
[k] Precise N2 numbering cannot be given because the NA of influenza B carries an insertion in the alignment compared to the NA of H3N2.

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