Association Between Neurological Outcomes and Timing of Physical Therapy Initiation Among Patients Treated for Aneurysmal Subarachnoid Hemorrhage: A Propensity-Adjusted Analysis

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Received, September 22, 2022; **Accepted,** April 03, 2023; **Published Online,** June 21, 2023.

BACKGROUND: Aneurysmal subarachnoid hemorrhage (aSAH) is a debilitating neurological disease associated with poor neurological outcomes.

OBJECTIVE: To evaluate the association between timing of physical therapy (PT) initiation and neurological outcomes among patients treated for aSAH.

METHODS: Patients receiving definitive aneurysm treatment at a single quaternary center (January 1, 2014-July 31, 2019) with data available on PT initiation and the number of sessions were analyzed. Patients were compared based on whether PT initiation was delayed (>24 hours after definitive aneurysm treatment) or nondelayed (≤24 hours after treatment). The primary outcome was a poor neurological outcome at last follow-up (modified Rankin Scale [mRS] score >2). A propensity-adjusted score was generated and included as a covariate in a logistic regression analysis.

RESULTS: Among 382 patients, 260 (68%) had delayed and 122 (32%) had nondelayed PT initiation. A significantly greater percentage of patients in the delayed PT group had an mRS score of >2 at last follow-up (42% [n = 110] vs 20% [n = 24]; $P < .001$). Among 298 patients with a Hunt and Hess (HH) grade <4, the percentage with an mRS score of >2 at last follow-up was significantly higher in the delayed (34% [62/184]) than nondelayed (18% [21/114]) PT group ($P = .006$). The logistic regression analysis showed that, among patients with an HH grade of <4, delayed PT initiation increased the risk of having an mRS score of >2 at follow-up (odds ratio = 1.90, 95% CI = 1.02-3.62, $P = .047$).

CONCLUSION: Delayed PT initiation after definitive aneurysm treatment was associated with poor neurological outcomes regardless of patient characteristics, neurological presentation, or aneurysm characteristics.

KEY WORDS: Aneurysmal subarachnoid hemorrhage, aSAH, Physical therapy

Neurosurgery Practice 2023;4(3):e00046. https://doi.org/10.1227/neuprac.0000000000000046

Aneurysmal subarachnoid hemorrhage (aSAH) can be a devastating neurological event and is associated with a 40% to 50% mortality rate.[1,2] aSAH disproportionately occurs among individuals 65 years or younger, causing potentially significant debilitation and loss of productive life years.[3] Patients with aSAH also often have prolonged hospital stays and poor neurological outcomes.[4,5] For example, the cognitive and motor sequelae of aSAH may lead to a reduction in quality of life and the

ABBREVIATIONS: aSAH, aneurysmal subarachnoid hemorrhage; **HH,** Hunt and Hess; **PT,** physical therapy.

Supplemental digital content is available for this article at neurosurgerypractice-online.com.

inability to optimally perform basic functions, such as standing, walking, or independent activities of daily living.[6,7]

Clinical observation suggests that early physical therapy (PT) after aSAH treatment is safe and may lead to improved functional outcomes for patients. Previous animal models have suggested favorable effects of motor training on functional outcomes.[8,9] Recent literature suggests that early PT may lead to improved functional outcomes after stroke.[10-12] Despite clinical expectations and animal models that demonstrate favorable effects of PT after cerebral injury, few large single-center studies examining the timing of PT initiation in patients treated for aSAH have been reported. This study analyzed the association between the timing of PT initiation and neurological outcomes at last follow-up among patients treated for aSAH at a single quaternary center.

METHODS

In accordance with retrospective studies of this nature, the study design was approved by St. Joseph's Hospital and Medical Center Institutional Review Board. The requirement for informed consent for study participation was waived because of the low risk to the patients and the study's retrospective nature. The study was conducted in accordance with Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

All patients treated for an aSAH at a single quaternary care center between January 1, 2014, and July 31, 2019, were retrospectively reviewed for PT metrics using a prospectively maintained institutional database. Inclusion criteria included documented PT initiation and the number of sessions. Exclusion criteria included lack of follow-up modified Rankin Scale (mRS) score data. The patients were compared on the basis of delayed vs nondelayed PT initiation. Delayed PT initiation was defined as the first PT session >24 hours after definitive aneurysm treatment, and nondelayed PT was defined as initiation ≤24 hours after definitive aneurysm treatment. A cutoff of 24 hours for delay of PT was determined using Euclidean distance analysis on favorable neurological outcome (mRS scores) at discharge with optimization of sensitivity (98.8%). This cutoff is also an institutional goal for PT initiation postoperatively. A supplemental cutoff was determined using the same Euclidean distance analysis with optimization of the sum of sensitivity and specificity. Definitive aneurysm treatment was defined as the index open or endovascular operation for treatment of the aneurysmal source of the SAH. Other information gathered included patient age, sex, Hunt and Hess (HH) grade, Fisher grade, Charlson Comorbidity Index, admission Glasgow Coma Scale score, aneurysm size, aneurysm location, and treatment type (open microsurgery or endovascular treatment). The primary outcome was a poor neurological outcome, defined as an mRS score of >2 at last follow-up. A subset of patients with an HH grade of <4 were analyzed to assess a cohort with less significant presenting symptoms to minimize potential bias on future functional outcomes. In the cohort of patients with an HH grade of <4, a propensity score–adjusted logistic regression analysis was conducted, adjusting for age, sex, HH grade, Fisher grade, Charlson Comorbidity Index, aneurysm type, size, and location, and number of PT sessions. PT sessions were individualized sessions with a licensed physical therapist based on improvement of muscle control, quality of movement, stability, and weight-bearing ability. Intervention was active or passive, depending on the status of the patient and administered 5 days a week postoperatively until discharge. More critical patients tended to receive more PT sessions because of their longer length of stay; in addition, those patients received priority if the PT service was overbooked.

Data were calculated as mean with SD, median (IQR), or number and percentage of patients. Statistical analyses, including data aggregation, exploratory analysis, and propensity adjustment, were performed using R, version 4.0.1 (R Foundation for Statistical Computing). Interval variables, such as patient characteristics, were analyzed with the use of an independent 2-sample t test, whereas categorical variables were analyzed using a χ^2 test. Mood's median test was used to test for difference in median values. A propensity-adjusted score was generated as the predicted probability for assignment to delayed vs nondelayed PT groups. Data were calculated as odds ratios (ORs) and 95% CIs. The score was used for covariate adjustment in a logistic regression analysis. Statistical significance was set at $P < .05$.

RESULTS

During the 5.5-year study period, 1014 patients were treated for aSAH and 382 patients met the study's inclusion criteria. Of these patients, 260 (68%) had delayed PT initiation and 122 (32%) had nondelayed initiation (Table 1). Age, sex, aneurysm size, and aneurysm type were found to be similar between the two cohorts ($P \geq .16$). The delayed PT cohort (n = 260) had a significantly higher percentage of patients with an HH grade of ≥ 4 than did the nondelayed PT cohort (n = 122) (29% [n = 76] vs 7% [n = 8]; $P < .001$), a Fisher grade of 4 (75% [n = 194] vs 51% [n = 62]; $P < .001$), and posterior circulation aneurysms (24% [n = 63] vs 13% [n = 16]; $P = .02$). The delayed cohort had a significantly lower mean (SD) Glasgow Coma Scale score at admission (11.4 [3.7]) than the nondelayed cohort (14.0 [1.7]) ($P < .001$). Treatment type (open microsurgery vs endovascular) was not significantly different between cohorts ($P = .46$). The mean (SD) number of PT sessions was significantly higher for the delayed PT cohort (6.1 [3.6] vs 5.2 [3.2]; $P = .03$). The delayed PT group also had a greater percentage of patients with an mRS score of >2 at last follow-up than the nondelayed PT group (42% [n = 110] vs 20% [n = 24]; $P < .001$). Mean (SD) follow-up duration in the delayed vs nondelayed cohorts varied significantly (599 [749] vs 436 [621] days; $P = .02$).

Among the entire study population, 298 patients had an HH grade of <4: 184 (62%) had delayed PT, and 114 (38%) had nondelayed PT (Table 2). A comparison of patient demographics and outcomes by Hunt and Hess grade in this cohort is shown in **Supplemental Table 1**, http://links.lww.com/NEUOPEN/A69. Similar to the results for all patients, a subanalysis of the patients with an HH grade of <4 showed that the delayed PT group averaged significantly more mean PT sessions than the nondelayed group (5.9 [3.4] vs 4.9 [3.1]; $P = .02$). In this group, the percentage of patients with an mRS score of >2 at last follow-up was also significantly higher in the delayed PT cohort (34% [62/184]) than in the nondelayed PT cohort (18% [21/114]; $P = .006$) (Table 2). The nondelayed PT cohort had lower proportions compared with the delayed cohort of seizures (5.3% [6/114] vs 14% [25/184], $P = .022$), noncerebrospinal

TABLE 1. Baseline Characteristics and Outcomes of Patients Treated for Aneurysmal Subarachnoid Hemorrhage by the Time of PT Initiation[a]

Characteristic	Delayed PT (n = 260)	Nondelayed PT (n = 122)	*P* value[b]
Age, mean (SD), y	56 (14)	54 (14)	.16
Sex			.42
Male	78 (30)	31 (25)	
Female	182 (70)	91 (75)	
Aneurysm location, anterior vs posterior			**.02**
Anterior	197 (76)	106 (87)	
Posterior	63 (24)	16 (13)	
Aneurysm location, by artery			>.99
ICA	16 (6.2)	17 (14)	
MCA	41 (16)	17 (14)	
VA	12 (5)	4 (3)	
AChA	2 (1)	3 (2)	
ACA	14 (5)	5 (4)	
ACoA	77 (30)	39 (32)	
PCoA	47 (18)	24 (20)	
PCA	8 (3)	2 (2)	
SCA	5 (2)	1 (1)	
BA	18 (7)	6 (5)	
AICA	20 (8)	3 (2)	
Aneurysm size, mean (SD), mm	6.1 (3.4)	6.1 (2.8)	.42
Aneurysm type			.32
Unknown/others	1 (0.4)	0 (0)	
Saccular	213 (82)	110 (90)	
Fusiform	18 (6.9)	4 (3)	
Dissecting	17 (6.5)	4 (3)	
Blister	11 (4.2)	4 (3)	
GCS score at admission, mean (SD)	11.4 (3.7)	14.0 (1.7)	**<.001**
GCS, median (IQR)	13 (8-15)	15 (13-15)	**<.001**
HH grade, median (IQR)	3 (2, 4)	2 (2, 3)	**<.001**
HH grade ≥4	76 (29)	8 (7)	**<.001**
Fisher grade, median (IQR)	4 (3, 4)	4 (3, 4)	**<.001**
Fisher grade 4	194 (75)	62 (51)	**<.001**
CCI, mean (SD)	1.69 (1.78)	1.39 (1.39)	.18
CCI, median (IQR)	1 (0-2.25)	1 (0-2)	.45
CCI ≥4	32 (12)	10 (8)	.31

TABLE 1. Continued.

Characteristic	Delayed PT (n = 260)	Nondelayed PT (n = 122)	*P* value[b]
Length of stay, mean (SD), d	22 (8)	17 (7)	**<.001**
Open surgical treatment	159 (61)	69 (57)	**.46**
Days to last FU, mean (SD)	599 (749)	436 (621)	**.02**
FU >180 d	123 (47)	48 (39)	.18
Postoperative events			
Seizure	43 (17)	8 (6.6)	**.007**
Deep vein thrombosis	22 (8.5)	4 (3.3)	.06
Pulmonary embolism	3 (1.2)	2 (1.6)	.66
Non-CSF infection	152 (58)	33 (27)	**<.001**
EVD	224 (86)	73 (60)	**<.001**
EVD infection	10/222 (4.5)	5/72 (6.9)	.37
Permanent shunt placement	76 (29)	13 (11)	**<.001**
Operative treatment complication	32 (12)	15 (12)	>.99
DCI	89 (34)	26 (21)	**.01**
Vasospasm	216 (83)	88 (72)	**.02**
Retreatment	15 (6)	8 (7)	.94
mRS score at discharge, median (IQR)	4 (3, 4)	3 (1, 4)	**<.001**
mRS score >2 at last FU	110 (42)	24 (20)	**<.001**
mRS score at last FU, median (IQR)	2 (1, 4)	1 (0, 2)	**<.001**
No. of PT sessions, mean (SD)	6.1 (3.6)	5.2 (3.2)	**.03**

ACA, anterior cerebral artery; AChA, anterior choroidal artery; ACoA, anterior communicating artery; AICA, anterior inferior cerebellar artery; BA, basilar artery; CCI, Charlson Comorbidity Index; CSF, cerebrospinal fluid; DCI, delayed cerebral ischemia; EVD, external ventricular drain; FU, follow-up; GCS, Glasgow Coma Scale; ICA, internal carotid artery; MCA, middle cerebral artery; mRS, modified Rankin Scale; PCA, posterior cerebral artery; PCoA, posterior communicating artery; PT, physical therapy; SCA, superior cerebellar artery; VA, vertebral artery.
[a]Nondelayed PT was defined as initiation ≤24 hours after definitive treatment; delayed PT was defined as initiation >24 hours after definitive treatment.
[b]Statistical tests performed: Wilcoxon rank-sum test, χ^2 test of independence, and Fisher exact test.
Data are presented as the number (%) of patients unless otherwise indicated. The total percentage for some categories may not equal 100% because of rounding.
Bold text indicates statistical significance (*P*<.05).

fluid infection (25% [29/114] vs 49% [91/184], *P* < .001), and placement of an external ventricular drain (57% [65/114] vs 81% [149/184], *P* < .001) (Table 2).

Risk factors for a poor neurological outcome defined by an mRS score of >2 at last follow-up (Table 3) were delayed PT initiation (OR, 1.90; 95% CI, 1.02-3.62; *P* = .047) and the number of PT sessions (OR, 1.16; 95% CI, 1.06-1.27; *P* = .001). Adjusting for the same variables, delayed PT initiation was also found to increase the length of stay by 2.64 days on average (95% CI, 1.34-3.95; *P* < .001) (Table 4). Similar trends were observed in a propensity score–adjusted logistic regression analysis conducted for all patients, regardless of HH grade (Tables 5 and 6): delayed PT and the number of PT sessions were significantly associated with an mRS score of >2 at last follow-up (*P* ≤ .01) and length of hospital stay (*P* < .001). Additional optimization of the cutoff value for PT delay to maximize sensitivity and specificity resulted in a cutoff of 5 days (specificity = 85.6%, sensitivity = 38.6%), which was outside of institutional protocols for postoperative PT. A propensity-adjusted model using this cutoff determined that a delay of 5 days, similar to a delay greater than 24 hours, was associated with poor functional outcomes (OR, 3.87; 95% CI, 1.95-7.83; *P* < .001) and an increased length of stay by 5.5 days (95% CI, 3.90-7.10; *P* < .001).

DISCUSSION

The findings of this study support an association between PT initiation timing and neurological outcome after aSAH treatment.

TABLE 2. Baseline Characteristics and Outcomes of Patients Treated for Aneurysmal Subarachnoid Hemorrhage With an HH Grade of <4 by the Time of PT Initiation[a]

Characteristic	Delayed PT (n = 184)	Nondelayed PT (n = 114)	*P* value[b]
Age, mean (SD), y	55 (14)	54 (14)	.49
Sex			.85
Male	50 (27)	29 (25)	
Female	134 (73)	85 (75)	
Aneurysm location, anterior vs posterior			.07
Anterior	143 (78)	99 (87)	
Posterior	41 (22)	15 (13)	
Aneurysm location, by artery			>.99
ICA	11 (6)	16 (14)	
MCA	24 (13)	16 (14)	
VA	7 (4)	4 (4)	
AChA	1 (1)	3 (3)	
ACA	11 (6)	5 (4)	
ACoA	60 (33)	37 (32)	
PCoA	36 (20)	22 (19)	
PCA	6 (3)	2 (2)	
SCA	3 (2)	1 (1)	
BA	12 (7)	6 (5)	
AICA	13 (7)	2 (2)	
Aneurysm size, mean (SD), mm	5.88 (3.35)	6.02 (2.74)	.19
Aneurysm type			.63
Unknown/others	1 (1)	0 (0)	
Saccular	154 (84)	103 (90)	
Fusiform	12 (7)	4 (4)	
Dissecting	10 (5)	4 (4)	
Blister	7 (4)	3 (3)	
GCS score at admission, mean (SD)	13.26 (2.40)	14.37 (1.11)	**<.001**
GCS, median (IQR)	14 (13-15)	15 (14-15)	**<.001**
HH grade, median (IQR)	2 (2, 3)	2 (2, 2)	**.002**
Fisher grade, median (IQR)	4 (3, 4)	3 (2, 4)	**<.001**
Fisher grade 4	123 (67)	55 (48)	**.002**
CCI, mean (SD)	1.62 (1.89)	1.37 (1.34)	.53
CCI, median (IQR)	1 (0-2)	1 (0-2)	.72
CCI ≥4	20 (11)	8 (7)	.37

TABLE 2. Continued.

Characteristic	Delayed PT (n = 184)	Nondelayed PT (n = 114)	*P* value[b]
Length of stay, mean (SD), d	21 (8)	16 (6)	**<.001**
Open surgical treatment	111 (60)	66 (58)	.77
Time to last FU, mean (SD), d	658 (795)	436 (619)	**.009**
FU > 180 d	90 (49)	45 (39)	.14
Postoperative events			
Seizure	25 (14)	6 (5.3)	**.02**
Deep vein thrombosis	13 (7.1)	4 (3.5)	.20
Pulmonary embolism	1 (0.5)	2 (1.8)	.56
Non-CSF infection	91 (49)	29 (25)	**<.001**
EVD	149 (81)	65 (57)	**<.001**
EVD infection	4/148 (2.7)	3/64 (4.7)	.43
Permanent shunt placement	49 (27)	11 (9.6)	**<.001**
Operative treatment complication	24 (13)	15 (13)	.98
DCI	54 (29)	22 (19)	.07
Vasospasm	149 (81)	83 (73)	.13
Retreatment	9 (5)	8 (7)	.61
mRS score at discharge, median (IQR)	3 (2, 4)	2 (1, 4)	**.002**
mRS score >2 at last FU	62 (34)	21 (18)	.006
mRS score at last FU, median (IQR)	1 (1, 3)	1 (0, 2)	**.02**
No. of PT sessions, mean (SD)	5.9 (3.4)	4.9 (3.1)	**.02**

ACA, anterior cerebral artery; AChA, anterior choroidal artery; ACoA, anterior communicating artery; AICA, anterior inferior cerebellar artery; BA, basilar artery; CCI, Charlson Comorbidity Index; CSF, cerebrospinal fluid; DCI, delayed cerebral ischemia; EVD, external ventricular drain; FU, follow-up; GCS, Glasgow Coma Scale; ICA, internal carotid artery; MCA, middle cerebral artery; mRS, modified Rankin Scale; PCA, posterior cerebral artery; PCoA, posterior communicating artery; PT, physical therapy; SCA, superior cerebellar artery; VA, vertebral artery.
[a]Nondelayed PT was defined as initiation ≤24 hours after definitive treatment; delayed PT was defined as initiation >24 hours after definitive treatment.
[b]Statistical tests performed: Wilcoxon rank-sum test, χ^2 test of independence, and Fisher exact test.
Data are presented as the number (%) of patients unless otherwise indicated. The total percentage for some categories may not equal 100% because of rounding.
Bold text indicates statistical significance (P<.05).

Specifically, a significantly higher proportion of patients with delayed PT initiation had a poor neurological outcome (mRS score >2) after adjusting for significant confounders. Accordingly, our study supports the importance of early PT initiation in patients after definitive aneurysm treatment.

Previous research examined the role of early PT in patient recovery after aSAH. In a cohort of patients treated for cerebral aneurysms, early rehabilitation was associated with an improved level of consciousness, functional status, mobility, and independence in activities of daily living for patients.[13] Clinchot et al[14] also found that improved cognitive orientation at discharge was predicted by earlier rehabilitation. Kara et al[15] similarly observed that functional independence in patients after SAH was greater in patients receiving regular supervised exercise with a physiotherapist as opposed to nonsupervised home exercise. Others found that patients in stroke units that practice early rehabilitation, initiated 24 to 72 hours after stroke, had a reduced time to first mobilization compared with usual care (rehabilitation after >7 days of bed rest).[16] Early mobilization was thereby associated with both a lower risk of medical complications[17] and a shorter length of hospital stay.[18] With the effectiveness of rehabilitation decreasing with increasing time after the initial neurological injury,[19] early interventions have proven to be integral to improved outcomes. Our analysis reinforces the utility of initiating PT early after aSAH treatment because poor neurological outcomes were associated with delayed PT in our patient cohort.

TABLE 3. Propensity-Adjusted Logistic Regression Model for an mRS Score of >2 at Last Follow-up Among Patients With an HH Grade of <4

Characteristic	OR	95% CI	*P* value
Delayed PT	1.90	1.02, 3.62	**.047**
No. of PT sessions	1.16	1.06, 1.27	**.001**
Age	1.02	0.97, 1.07	.32
Male sex	0.55	0.18, 1.74	.30
CCI	1.09	0.57, 2.43	.81
HH grade	1.26	0.12, 17.3	.85
Fisher grade	0.65	0.04, 13.6	.76
Open treatment	0.61	0.22, 1.79	.35
Aneurysm type	1.44	0.70, 3.20	.34
Aneurysm size	1.08	0.86, 1.34	.50
Anterior location	1.19	0.09, 13.0	.89
Propensity score	49.8	0.00, 100	.80

CCI, Charlson Comorbidity Index; HH, Hunt and Hess; mRS, modified Rankin Scale; OR, odds ratio; PT, physical therapy.
Bold text indicates statistical significance (*P*<.05).

Historically, better clinical status at admission predicts better patient outcomes. Dombovy et al[20] found that patients who presented with higher HH grades had worse functional outcomes.

TABLE 4. Propensity-Adjusted Logistic Regression Model for Hospital Length of Stay Among Patients With an HH Grade of <4

Characteristic	exp(Beta)	95% CI	*P* value
Delayed PT	2.64	1.34, 3.95	**<.001**
No. of PT sessions	1.15	0.96, 1.35	**<.001**
Age	−0.11	−0.21, −0.01	**.03**
Male sex	1.16	−1.16, 3.49	.32
CCI	1.24	−0.26, 2.74	.10
HH grade	5.66	0.28, 11.0	**.04**
Fisher grade	6.46	0.28, 12.6	**.04**
Open treatment	2.28	−0.02, 4.59	.05
Aneurysm type	1.92	0.25, 3.58	**.02**
Aneurysm size	−0.49	−0.97, −0.01	**.046**
Anterior location	−3.68	−9.15, 1.79	.19
Propensity score	−50.8	−115, 13.8	.12

CCI, Charlson Comorbidity Index; HH, Hunt and Hess; PT, physical therapy.
Bold text indicates statistical significance (*P*<.05).

TABLE 5. Propensity-Adjusted Logistic Regression Model for an mRS Score of >2 at Last Follow-up for All Patients

Characteristic	OR	95% CI	*P* value
Delayed PT	2.20	1.26, 3.96	**.007**
No. of PT sessions	1.09	1.02, 1.17	**.01**
Age	1.02	0.99, 1.04	.14
Male sex	0.84	0.43, 1.64	.61
CCI ≥4	3.83	1.58, 9.67	**.003**
HH grade ≥4	8.09	0.56, 146	.14
Fisher grade 4	2.61	0.40, 19.3	.33
Open treatment	0.92	0.45, 1.98	.84
Aneurysm type	1.29	0.92, 1.82	.14
Aneurysm size	1.01	0.92, 1.10	.90
Anterior location	0.40	0.09, 1.56	.20
Propensity score	0.01	0.00, 753	.41

CCI, Charlson Comorbidity Index; HH, Hunt and Hess; mRS, modified Rankin Scale; PT, physical therapy.
Bold text indicates statistical significance (*P*<.05).

Kassell et al[21] similarly observed higher admission motor responses in patients with better outcomes. Guclu-Gunduz et al[13] showed that patients with a worse clinical status at onset tended to have a poorer functional status at discharge. Interestingly, we found that patients with poorer neurological status at admission (HH grade ≥4) were significantly more likely to be in the delayed PT cohort. The severity of the patient's condition after aSAH may prevent the initiation of timely PT, which may limit potential recovery.

In a study by Kim et al,[8] after hemorrhagic strokes were induced in rats, animals that underwent motor training had increased expression of favorable neural growth factors and an increase in potential for neuroplasticity. Physical therapy in other animal models, including acrobatic and aerobic training paradigms, has been associated with increased dendritic reorganization,[22] astrocytic plasticity,[23] synaptogenesis,[9] and even neurogenesis.[24] Similarly, physical exercise has been shown to enhance the expression of neurotrophic factors,[25] induce long-term potentiation,[26,27] stimulate angiogenesis,[28,29] and stimulate new neuronal generation.[27,28,30] Therefore, targeted physical activity and rehabilitative training after aSAH can promote neuroplasticity, allowing the brain to recover and adapt after trauma.

Even in patients without evident motor deficits, abnormalities in information processing, behavior, emotional control, memory, learning, language, and social interactions have been widely reported in patients after an aSAH.[31-34] Although early PT is integral to improved functional motor outcomes in patients, it may not be sufficient to effectively address the cognitive and social deficits burdening patients and families.[14] With physical and occupational therapies focusing on impairments in mobility and motor function, it

TABLE 6. Propensity-Adjusted Logistic Regression Model for Length of Hospital Stay for All Patients

Characteristic	exp(Beta)	95% CI	*P* value
Delayed PT	3.00	1.61, 4.38	**<.001**
No. of PT sessions	1.19	1.01, 1.38	**<.001**
Age	−0.04	−0.10, 0.01	.15
Male sex	−1.39	−3.11, 0.33	.11
CCI ≥4	−1.14	−3.51, 1.23	.34
HH grade ≥4	−0.49	−7.48, 6.50	.89
Fisher grade 4	−0.48	−5.47, 4.52	.85
Open treatment	−0.60	−2.53, 1.34	.54
Aneurysm type	0.34	−0.56, 1.25	.45
Aneurysm size	0.08	−0.16, 0.32	.51
Anterior location	2.60	−0.98, 6.18	.15
Propensity score	21.6	−9.17, 52.4	.17

CCI, Charlson Comorbidity Index; HH, Hunt and Hess; PT, physical therapy.
Bold text indicates statistical significance (*P*<.05).

will be important to explore how the early initiation of cognitive rehabilitation can affect functional outcomes in patients after aSAH.

Although no unanimous standards of care exist for early rehabilitation, Tong et al[35] found favorable functional outcomes in patients using early intense mobilization in the 24 to 48 hours after injury. However, Reuter et al[36] demonstrated that very early rehabilitation is less frequently applied to patients after hemorrhagic, rather than ischemic, stroke. The authors attributed this hesitancy of physicians to initiate early rehabilitation in patients with intracerebral hemorrhage to concerns over blood pressure oscillations associated with physical activity[37] because excessive blood pressure variability has been associated with poor outcomes.[38] However, a recent review by Jafari and Damani[39] suggests that more severe intracerebral hemorrhage may actually induce greater blood pressure variability because of autonomic dysfunction of the baroreceptor reflex. With our study finding of improved outcomes in patients receiving nondelayed PT, the risks associated with blood pressure variations induced by physical exercise are likely outweighed by the intrinsic benefits of early, multimodal rehabilitative interventions after aSAH.[40]

Limitations

Because of its retrospective and single-institution study design, this analysis is potentially limited by selection bias, incompleteness of existing medical records, and quality of data extracted. We did not assess or account for baseline motor deficits before aSAH and before PT initiation after aSAH treatment, which could warrant a greater number of PT sessions and earlier PT initiation. A major limitation is that patients with more severe postoperative deficits and neurological function could have had PT initiation delayed because additional medical management and rest were needed, causing nondelayed PT initiation to be more frequent among patients who had already neurologically improved after treatment. We attempted to account for this factor by analyzing the subgroup of patients with an HH grade of <4 and by adjusting for potentially confounding variables. Future prospective studies with regimented PT initiation scheduling are needed to attempt to mitigate this confounding variable. This study and analysis also failed to account for postoperative events that may contribute to morbidity because of the possibility of a correlation between each type of morbidity and delayed mobilization of the patient. With the adjustment for preoperative and baseline differences, a delayed initiation of PT can help to serve as a prognostic tool for future hospital stay and future neurological outcome. Intracranial pressure is a useful preoperative tool that could have been an effective measure of severity, showing an effect on future morbidity and mortality, but we were not able to retrospectively assess this possibility adequately. Finally, this study and analysis are not structured to establish causality, only a prognostic association; a future prospective study is needed for more in-depth analysis.

CONCLUSION

Delayed PT initiation in patients after definitive aneurysm treatment was associated with poor neurological outcome regardless of patient characteristics, neurological presentation, or aneurysm characteristics. Our study results suggest that early initiation of PT could be clinically important immediately after aSAH treatment. Further multicenter prospective studies assessing matched patient cohorts receiving delayed and nondelayed PT initiation should be pursued to further elucidate this association.

Funding

This study did not receive any funding or financial support.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article. Andrew F. Ducruet is a consultant for Medtronic, Penumbra, Stryker, Cerenovus, Koswire, Balt, and Oculus. Ruchira M. Jha has nonrelated grants from NIH, Chuck Noll Foundation, and Barrow Neurological Foundation and is a paid consultant at Biogen.

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Acknowledgments

We thank the staff of Neuroscience Publications at Barrow Neurological Institute for assistance with manuscript preparation.

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Supplemental Table 1. Baseline characteristics, physical therapy metrics, and outcomes of patients treated for aneurysmal subarachnoid hemorrhage by Hunt and Hess grade.

COMMENTS

The authors retrospectively investigated a possible temporal relationship of physiotherapy initiation and outcome, based on a prospectively maintained database of aneurysmal SAH patients. Besides a well-described methodology, reasonable sample size and follow-up duration are strengths of this work. The presented data show how more severely affected SAH patients may not be able to benefit from early physiotherapy; however, the causal relationship to poor outcomes in this cohort is yet to be substantiated. As such, a prospective assessment on this topic is needed, as advocated by the authors. The current study was not designed to clarify whether early initiation of physical therapy may also have a beneficial effect on some major drivers of poor outcome after SAH, induced by sequelae such as hydrocephalus, DCI, and others. Early and structured physiotherapy and rehabilitation have repeatedly proven to be beneficial in SAH and stroke, and therefore, further elucidation is worthwhile.

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This article presents intriguing findings regarding the association between the timing of physical therapy (PT) initiation and neurological outcomes in patients with aSAH. However, on careful evaluation, several limitations must be addressed before conclusions are drawn.

First, the association between early PT initiation and improved outcomes in this population has been previously demonstrated. Unsurprisingly, patients with poor-grade SAH may have delayed PT due to their medical condition and worse results. It is crucial to consider the potential confounding effects of the severity of SAH at presentation (Hunt and Hess grade) on both PT initiation and products as the sickest patients may be less likely to receive early PT.

Additionally, the manuscript lacks information on other critical factors that may influence outcomes in patients with aSAH, such as intracranial pressure (ICP) management, delayed cerebral ischemia, hydrocephalus, in-hospital complications (eg, infections, myocardial dysfunction, seizures), and type of treatment (open or endovascular). These factors could significantly impact PT initiation and neurological outcomes, and their exclusion from the analyses may limit the interpretation of the results.

Furthermore, it is essential to differentiate between poor outcomes attributed to the severity of SAH at presentation (Hunt and Hess grade) and the potential inability to benefit from PT due to the patient's medical condition. A more precise analysis based on quality and other relevant factors could provide a more comprehensive understanding of the findings.

In conclusion, while the manuscript presents exciting findings regarding the timing of PT initiation in patients with aSAH, significant limitations need to be addressed before making definitive conclusions. Further research incorporating a more comprehensive analysis of relevant factors, such as ICP management, delayed cerebral ischemia, and in-hospital complications, is needed to better understand the impact of PT initiation timing on neurological outcomes in this patient population. In addition, it is essential to consider the complexities of managing patients with aSAH and the potential confounding effects of various factors to guide clinical decision-making effectively.

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