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Post-stroke lateropulsion and rehabilitation outcomes: a retrospective analysis

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Competing interests
The authors declare that there is no conflict of interest.

ABSTRACT

Purpose

A person with post-stroke lateropulsion actively pushes themselves toward their hemiplegic side, or resists moving onto their non-hemiplegic side. This study aimed to determine the association of lateropulsion severity with:

- Change in function (Functional Independence Measure – FIM) and lateropulsion severity (Four-Point Pusher Score – 4PPS) during inpatient rehabilitation;
- Inpatient rehabilitation length of stay (LOS);
- Discharge destination from inpatient rehabilitation.

Methods

Retrospective data for 1,087 participants (aged ≥65 years) admitted to a stroke rehabilitation unit (2005-2018) were analysed using multivariable regression models.

Results

Complete resolution of lateropulsion was seen in 69.4% of those with mild lateropulsion on admission (n=160), 49.3% of those with moderate lateropulsion (n=142), and 18.8% of those with severe lateropulsion (n=181). Average FIM change was lower in those with severe lateropulsion on admission than those with no lateropulsion ($p<0.001$). Higher admission 4PPS was associated with reduced FIM efficiency ($p<0.001$), longer LOS ($p<0.001$), (adjusted mean LOS: 35.6 days for those with severe lateropulsion versus 27.0 days for those without), and reduced likelihood of discharge home ($p<0.001$).

Conclusion

Post-stroke lateropulsion is associated with reduced functional improvement and likelihood of discharge home. However, given a longer rehabilitation duration, most stroke survivors with moderate to severe lateropulsion can achieve important functional improvement.

Key words: lateropulsion, pusher syndrome, stroke, rehabilitation, recovery

Introduction

Lateropulsion is a common impairment of postural control and balance that is associated with stroke [1, 2]. It is believed that an altered sense of verticality causes an affected person to actively push their body toward their hemiparetic side, or to actively resist weight acceptance onto their nonparetic side [1, 3, 4]. Reported rates of lateropulsion after stroke vary from 9 – 63% [5]. This large variability in reported incidence is likely due to use of different outcome measures, assessment at different time intervals post-stroke, and different characteristics of participants included in the studies [5].

Lateropulsion was initially thought to exist as part of a “pusher syndrome”, first described in 1985 [1]. The initial description of the syndrome included body lateropulsion toward the side contralateral to the brain lesion, contralateral neglect, anosagnosia and apraxia [1]. Davies [1] reported that greater numbers of patients with right-sided brain lesions than left-sided lesions exhibit the syndrome, and that those with left-sided lesions and lateropulsion either had very severe aphasia or no speech deficits at all. In part of the Copenhagen Stroke Study, Pedersen et al. [2], however, reported no differences in the incidence of neglect and anosagnosia in patients with and without lateropulsion, and no association of lateropulsion with side of brain lesion. Although the initial assumption that lateropulsion exists as part of a ‘syndrome’ has been rejected, the term “pusher syndrome” is still commonly used in reference to lateropulsion toward the hemiplegic side [2, 6, 7, 8].

The relationship between lateropulsion, brain lesion side and presence of additional stroke impairments, as well as the implication of lateropulsion for recovery, remain poorly understood. Previous studies found no correlation between lateropulsion severity and lesion side [2, 9, 10], while others [11, 12, 13, 14, 15] found increased prevalence, delayed recovery from lateropulsion, or poorer functional outcome to be associated with right-sided lesions. In a study including 169 participants with lateropulsion, Babyar et al. [14] examined the influence of specific stroke impairments on the time needed to recover from lateropulsion, and found that 90% of participants with only motor impairment achieved resolution of lateropulsion before discharge, while only 37% of participants with a combination of motor, proprioceptive, hemianopic or visuo-spatial impairment achieved resolution of lateropulsion during inpatient rehabilitation. Lateropulsion resolution was achieved in 59% of participants with two of these post-stroke deficits present, indicating that recovery from lateropulsion can be affected by the presence and severity of other post-stroke impairments [14]. In another study including 134 participants with post-stroke lateropulsion, Babyar et al. [15] found that in participants with left-sided stroke, older age and greater motor impairment on admission were associated with persistent lateropulsion on discharge; whereas in participants with right-sided stroke, older age, greater limb placement error on admission, and lower cognitive FIM scores were associated with persistent lateropulsion on discharge. Pedersen et al. [2] did not find prevalence of neglect to be significantly higher in those with post-stroke lateropulsion versus those without lateropulsion. However, Lafosse et al. [12] found a higher prevalence of inattention among those with contraversive lateropulsion, particularly in those with right-sided strokes and Danells et al. [11] noted longer duration of lateropulsion symptoms to be associated with the presence of spatial neglect in a study including 65 participants, 39 of whom had lateropulsion. There is some inconsistency amongst studies using different Scale for Contraversive Pushing (SCP) cut-off points to define lateropulsion[16]. The majority of studies using the SCP [3, 10, 13] required score ≥1 in each of the three domains to indicate the presence of pushing. Although Danells et al. [11] defined pushing as an SCP total score ≥1, 87% of participants with pushing in their study showed SCP ≥3 on initial assessment. As it is not stated whether the SCP scores ≥3 noted by Danells et al. [11] represented scores ≥1 in each domain, severity of lateropulsion in this cohort may have been lower than in studies defining lateropulsion as present only when SCP≥1 scores were seen in each domain. The majority of previous studies represent relatively small cohorts, so there is a need for larger datasets to clarify the relationship between lateropulsion and recovery from lateropulsion, with brain lesion side, and presence of additional impairments.

It is apparent from a number of small cohort and case-control studies that the presence of lateropulsion after stroke results in significantly slower functional recovery and longer inpatient length of stay (LOS) [2, 9, 10, 11, 17] (table 1).

INSERT TABLE 1 ABOUT HERE

Babyar et al. [15] reported similar average LOS among participants that did and did not recover from lateropulsion during post-stroke rehabilitation, but suggested that this lack of difference was likely attributable to funding constraints on duration of inpatient stay rather than potential for further recovery. These comparisons are based on dichotomous measures (presence or absence of lateropulsion). Greater understanding of the relationship between lateropulsion severity and LOS is required to inform resource planning for rehabilitation for this patient group.

There is a lack of agreement among previous studies about the association of lateropulsion with discharge destination. Although some authors found lateropulsion to be associated with reduced likelihood of discharge home [2, 10], others reported only slightly higher (non-significant) percentages of participants without lateropulsion to be discharged home [9, 11].

While Danells et al. [11] found that all participants with early resolution of pushing behaviours were discharged home, only half of those with persistent pushing at three months were discharged home. Sub-group analyses were prevented by low numbers in this study. It appears that lateropulsion reduces the likelihood of discharge home; however, longer rehabilitation duration to enhance functional recovery may increase likelihood of returning home [9, 11, 17]. Disagreement among studies could be related to variation in timing and tools used for measurement of lateropulsion, as well as variation among health services and settings in terms of rehabilitation funding and allowance for longer LOS where required.

When investigating the effect of lateropulsion on functional recovery, there is a need to control for the presence and severity of additional impairments, to determine whether longer rehabilitation duration impacts recovery of lateropulsion, independent of other factors. This is essential because entry criteria at some rehabilitation centres may lead to exclusion of people with lateropulsion who have significant potential to improve their level of function, if given the opportunity for sufficient rehabilitation.

It is evident from the literature that more data are needed to clearly establish relationships between lateropulsion and rehabilitation potential (functional improvement and discharge destination), expected recovery rates, and the influence of additional impairments, such as inattention, on rehabilitation outcome. This study aims to determine the association of lateropulsion severity after stroke, as measured by the Four-Point Pusher Score (4PPS), with:

1. Functional change during inpatient rehabilitation, as measured by the Functional Independence Measure (FIM);
2. Change in lateropulsion (4PPS) during inpatient rehabilitation;
3. Length of stay (LOS) (days) in inpatient rehabilitation;

4. FIM efficiency during rehabilitation (FIM change / LOS); and
5. Discharge destination (categorical scale) after inpatient rehabilitation.

Methods

Design

This was a retrospective, observational cohort study that used data from a prospectively collected clinical database. The study methodology conformed to the STROBE statement for observational studies.

Setting

The study was undertaken within a Stroke Rehabilitation Unit (SRU) in a secondary level hospital.

Ethical considerations

This study was approved by the University Human Research Ethics Committee (2019-00501) and by the Health Care Group as Quality Activity 27180 / 34609.

Participants

All consecutive admissions to the SRU from November 2005 – December 2018 were included in the retrospective analysis. Included participants were >65 years of age, had a diagnosis of acute stroke confirmed by brain imaging and review by a stroke physician or neurologist, and were referred for rehabilitation. Patients with bilateral stroke, lateral medullary syndrome, and those who were non-ambulant prior to stroke were excluded from these analyses.

Data collection

The SRU maintains a prospectively collected clinical database, containing data from all admitted patients. Collected information includes patient demographics including the Oxford

Stroke Classification [18], and details of pre-stroke mobility and domicile, and diagnosis. Upon admission to, and discharge from, the SRU, all patients undergo assessment using validated instruments including the 4PPS, FIM, and mRS. Discharge assessment was not typically performed for patients who had subsequent adverse events, were transferred back to an acute hospital or died during their admission. Presence of neglect or inattention at admission, noted by a physician, physiotherapist or occupational therapist, was recorded. As the SRU has shown a trend toward shorter LOS in recent years due to improved efficiencies in team processes, calendar year of admission was included as a variable for analysis.

Admission and discharge instrument scores were recorded onto individual case-report forms and subsequently entered in the clinical database. An independent audit of data from 115 randomly selected participants was performed to ensure the integrity of data entry. Where a discrepancy occurred, five cases preceding and five cases succeeding the discrepancy were also assessed to detect any systematic errors. Agreement between the forms and database entry occurred in 94% of audited records. Discrepancies were checked against the Quality of Care Registry (Western Australian Department of Health register containing details for all public inpatient rehabilitation admissions, including admission and discharge dates and FIM scores).

Four Point Pusher Score (4PPS)

In the 4PPS, a score of zero indicates absence of lateropulsion, scores of one and two indicate mild and moderate lateropulsion respectively, and a score of three indicates severe lateropulsion (Supplementary File 1). The Scale for Contraversive Pushing (SCP) [3, 19] and the Burke Lateropulsion Scale (BLS) [20] were used in previous studies to measure lateropulsion [21]. A review compared the SCP (and modified versions) with the BLS, and found the BLS to be more sensitive in identifying lateropulsion [21]. The BLS was recommended for use in research over the SCP [21]. The 4PPS, which is commonly used by clinicians in Australia, has been validated against both of these scales, and agreement with the BLS was found to be excellent [5].

Functional Independence Measure (FIM)

The FIM is a 126-point scale that measures burden of care and is divided into motor (13 components) and cognitive scores (five components) [22]. The Minimum Clinically Important Difference (MCID) is 22 [23]. Although no Minimal Detectable Change (MDC) is published for FIM post stroke, the MDC for traumatic brain injury is 8.92 [24]. The FIM is assessed and recorded by credentialed clinicians within 72 hours of rehabilitation admission and discharge. A FIM efficiency measure was created by dividing the change in FIM during inpatient rehabilitation by the rehabilitation LOS (days).

Modified Rankin Scale (mRS)

The influence of lateropulsion on rehabilitation outcome is likely confounded by stroke severity. There is wide variation globally in scales used to measure stroke severity and post-stroke disability [25]. The National Institute of Health Stroke Scale (NIHSS) is most commonly used to assess stroke severity and to predict recovery, survival and discharge destination [25]. As the NIHSS does not measure function; measures of dependence, such as the mRS, Barthel Index, and Functional Independence Measure (FIM), are more suited to stroke rehabilitation trials [25]. The World Health Organisation Disability Assessment Schedule (WHODAS 2.0) was compared against the mRS and FIM in patients with subacute stroke, categorised by stroke severity as measured by the NIHSS [25]. The NIHSS at admission to rehabilitation was very strongly correlated with mRS and FIM scores on discharge from rehabilitation, and proxy WHODAS ratings were strongly correlated with NIHSS on rehabilitation admission and mRS on rehabilitation discharge, as well as being very strongly correlated with FIM scores on discharge [25]. Although it is a measure of disability, the mRS is closely correlated to stroke severity, stroke location and lesion volume, Oxford Stroke Classification[18] type, and NIHSS score [26]. While the mRS is less sensitive to change in a patient's functional ability than the NIHSS [27], it is may be used as an indicator of stroke severity and post-stroke disability [25, 26].

Data Analysis

Equality of proportions and means were assessed using Chi-squared and F tests respectively. Generalised linear models using the most appropriate probability distribution and canonical link functions were used to assess the associations between outcomes and exposure variables alone and with other covariates. Linear regression models were used to model change in FIM scores, logistic models used to estimate associations with improving 4PPS scores, negative binomial models used to assess LOS, and Poisson regression used to assess FIM efficiency. Pearson or Hosmer-Lemeshow goodness-of-fit tests were performed for Poisson and logistic models. The distributions of model residuals were also assessed for systematic bias. Alternative functional form of continuous independent variables age, LOS and admission FIM were tested where appropriate. All were included as linear covariates. The presence of significant interaction terms between admission 4PPS and other covariates were also assessed, but none were observed. Data were analysed using Stata 16 (StataCorp, College Station, Tx).

Results

Clinical data were available for 1,206 SRU admissions. After excluding those aged less than 65 years (n=4), those with bilateral or midline strokes (n=45), those with lateral medullary syndrome (n=11) and those who were non-ambulant prior to stroke (n=3), data from 1,147 participants remained eligible for inclusion. A further eight participants without an admission 4PPS recorded were excluded, as were nine patients with invalid data entry values that could not be corrected. Missing discharge scores for 4PPS and FIM were noted for participants who died during their admission, had subsequent adverse events, or were transferred to an acute hospital (n=39). This left 1,087 participants in the final study cohort for whom complete outcome data was available.

The average age of participants in this study was 79 years (SD 7.5) with slightly more males than females (n=563, 51.8%). Almost half of all participants had an Oxford Class of Partial Anterior Circulation Stroke (PACS), most strokes were due to ischaemia, and one third of patients had inattention noted on admission (table 2). The degree of lateropulsion at admission to the SRU, as measured by 4PPS, did not vary with participant age or sex, but it did vary by stroke-related measures (table 2). Higher 4PPS at admission tended to be associated with haemorrhagic strokes, Total Anterior Circulation Stroke (TACS) Oxford Classification, and presence of inattention. Of those with admission 4PPS of three, the majority (63.3%) had right-sided strokes.

INSERT TABLE 2 ABOUT HERE

Association between admission 4PPS and functional change: FIM

Median FIM scores increased during rehabilitation for participants at all levels of 4PPS at admission (figure 1). To investigate whether the degree of improvement in function was the same for all admission 4PPS levels, a linear regression model of the change in FIM after taking the admission FIM (baseline) into account was constructed. In this simple model, there was no difference in the degree of functional improvement for admission 4PPS of zero, one and two. However, the average change in FIM scores for participants admitted with 4PPS of three was significantly lower than patients admitted with 4PPS of zero (-12.2: 95%CI -9.2 - -15.2, p<0.001).

INSERT FIGURE 1 ABOUT HERE

Multivariable linear regression analysis was then performed to investigate whether this association of admission 4PPS of three with reduced improvement in FIM remained after taking other potentially confounding factors into account (table 3). After controlling for participant age, stroke type and Oxford Classification, LOS in acute care prior to rehabilitation and cognitive and total FIM scores at admission, the association of reduced functional improvement with higher 4PPS at admission remained. Evidence is now suggestive of a trend of lower improvement in FIM scores with all levels of lateropulsion at admission, although the greatest effect was still observed in participants with admission 4PPS of three.

INSERT TABLE 3 ABOUT HERE

Other factors associated with lower FIM change were increasing age, longer acute hospital LOS, higher FIM on admission to rehabilitation, lower cognitive FIM at admission, ischaemic stroke, and TACS Oxford Stroke Classification. Variables tested, but not found to be associated with FIM change were: sex, presence of inattention on admission, mRS at admission, side of stroke, year of admission and residential location.

Change in 4PPS

Among the 483 participants who were admitted with evidence of lateropulsion (4PPS ≥1), 4PPS change by time of discharge was investigated (table 4). Overall, improvement in 4PPS was seen in three-quarters of all participants (n=367; 76.0%) with 215 (44.5%) showing no sign of laterpulsion at discharge (4PPS=0).

INSERT TABLE 4 ABOUT HERE

A multivariable logistic regression model was used to investigate which participant and stroke-related factors might be associated with improvement in 4PPS. Participants admitted with 4PPS of two or three had approximately three times the odds of improving compared to participants admitted with 4PPS of one (OR 3.2: 95%CI 18-5.9 and OR 2.7: 95%CI 1.5-4.9 respectively). Other factors associated with reduced odds of improvement in 4PPS during rehabilitation were increasing age (OR 0.96: 95%CI 0.93-0.99), increasing admission mRS (OR: 0.49: 95% CI 0.30- 0.79), longer acute LOS (OR: 0.97, 95% CI: 0.95- 0.99), and TACS Oxford Classification (OR 0.44: 95% CI 0.20-0.97). Variables tested, but not found to be associated with change in 4PPS were admission total FIM, sex, cognitive FIM, type of stroke or presence of inattention.

Association between 4PPS and rehabilitation LOS

The mean rehabilitation LOS increased by admission 4PPS. For participants scoring zero on admission 4PPS, mean rehabilitation LOS was 21 (SD 14) days, followed by 34 (SD 17) days for participants with 4PPS of one, 44 (SD 22) days for participants with 4PPS of two and 51

(SD 21) days for participants with an admission 4PPS of three. This equated to a 2.4 (95%CI 2.2-2.6) fold difference in rehabilitation LOS between admission 4PPS of zero and three.

A multivariable negative binomial regression model showed that the strong association between rehabilitation LOS and admission 4PPS remained after controlling for other factors, however, the magnitude of the association was reduced from 2.4-fold to 1.3-fold and ranged from 27.0 to 35.6 days (table 5). This equated to an average rehabilitation LOS 8.6 (95%CI 5.4-11.7) days longer for patients with severe laterpulsion compared to patients without laterpulsion.

Other factors associated with shorter rehabilitation LOS included more recent calendar year of admission (IRR 0.95, 95%CI 0.94-0.96) and higher admission FIM score (IRR 0.99, 95%CI 0.99-0.99). Factors associated with longer LOS were higher mRS (IRR 1.07, 95%CI 1.01-1.12) and presence of inattention (IRR 1.097, 95%CI 1.02-1.16. Side of stroke, Oxford Classification, age, and sex were not significantly associated with rehabilitation LOS.

INSERT TABLE 5 ABOUT HERE

Association between 4PPS and FIM efficiency

FIM efficiency (change in FIM/rehabilitation LOS) was used to assess the rate of change of functional improvement. FIM scores decreased over the rehabilitation stay for 20 participants (1.8%) resulting in a negative change in FIM values. Negative FIM change in seven of these participants were due to acute adverse events and clinical deterioration during admission. Remaining negative FIM changes were seen as score reduction less than the MDC for the

FIM. As the aim of this study was to assess rate of functional improvement, these cases were excluded from the analysis. Of the remaining 1,066 participants who showed improved FIM scores during rehabilitation, the rate of functional improvement was on average 1.3 (95%CI 1.2-1.4) FIM unit increases per day for participants with 4PPS of zero at admission but only 0.5 (95%CI 0.4-0.6) FIM unit increases per day for participants with admission 4PPS of three.

After controlling for potential confounders, higher admission 4PPS remained associated with reduced FIM efficiency with the magnitude of the effects also relatively unchanged (table 6). Other factors associated with lower FIM efficiency were older age and longer acute LOS. Greater FIM efficiency was associated with more recent calendar year of admission and Posterior Circulation Stroke (POCS) Oxford Classification.

INSERT TABLE 6 ABOUT HERE

Discharge destination

The association of admission 4PPS with discharge destination was investigated. Only participants who were living at home without need for a carer before their stroke admission were included in this analysis (n=1,005, 92.5%). The remaining cases were either living in residential care facilities (n=24) or home with a carer (n=58) prior to their stroke. Just over one third (n=373, 37.5%) of participants admitted from home were discharged home without a carer. This varied by admission 4PPS with 53.1% (n=299) of participants with admission 4PPS of zero being discharged home, compared to 24.3% (n=36), 22.8% (n=29) and 7.2% (n=12) of participants with admission 4PPS of one, two or three respectively (Chi-square p-value <0.001). When the proportion of participants discharged home were stratified by discharge 4PPS status, 45.5% of participants with a discharge 4PPS of zero were discharged home without a carer compared to 21.2% of participants with 4PPS of one, 2.8% of participants with 4PPS of two and no participants with discharge 4PPS of three.

Logistic regression was used to assess whether the association of admission 4PPS with home discharge remained after taking other post stroke disability factors into account. The predicted probability of discharge home for those with no lateropulsion was 0.41 (95%CI 0.37-0.45) after taking admission FIM, rehabilitation LOS, presence of inattention, and age into account. As admission lateropulsion severity increased, the predicted probability of discharge home reduced to 0.30 (95%CI 0.23-0.38) for 4PPS of one, 0.37 (95% CI 0.29-0.46) for 4PPS of two and 0.25 (95% 0.15-0.36) for 4PPS of three.

Discussion

Using retrospective data from the largest study of stroke survivors with lateropulsion (n=483 with lateropulsion) published to date, this study aimed to examine the associations between post-stroke lateropulsion and functional outcome following rehabilitation, rehabilitation LOS, and discharge destination.

These data demonstrate that lateropulsion severity improved during rehabilitation stay in most people, regardless of 4PPS on admission to rehabilitation, and that those with admission 4PPS of two had the greatest odds of some improvement. This may be related to the fact that average rehabilitation LOS for those with 4PPS of two was ten days longer than those with mild lateropulsion (4PPS of one), as stroke survivors with 4PPS of one were likely to be discharged when they were functionally able to manage at home, regardless of resolution of lateropulsion. It remains unknown whether mild lateropulsion is also likely to show greater improvement, with longer duration of rehabilitation. A majority (75%) of participants with severe lateropulsion on admission (4PPS of three) showed some improvement in lateropulsion severity during their admission. It was found that, even in severe cases, lateropulsion improved with rehabilitation in the majority of stroke survivors. This is important because people with severe strokes are at risk of exclusion from rehabilitation due to a perceived poor potential for recovery when, as demonstrated by these data, most have potential for significant recovery.

Factors that were associated with poorer lateropulsion resolution were greater stroke-related disability (higher mRS on admission), older age, longer acute LOS, and TACS Oxford Classification (indicating greater stroke severity). In agreement with Babyar et al. [15], this study showed older age to be associated with poorer recovery from lateropulsion. In contrast to previous reports [13, 15, 17] suggesting that right sided-stroke was associated with delayed or poorer recovery from lateropulsion, these data did not suggest that side of stroke was significantly associated with recovery from lateropulsion. However, of note, in this cohort of 192 participants with severe lateropulsion (4PPS of three) on admission, 63.3% had right-sided strokes. In contrast to Danells et al. [11] but in agreement with Babyar et al. [15], presence of inattention was not found to be associated with recovery from lateropulsion. Cognitive FIM score was also not related to recovery from lateropulsion. Some of these variations in findings may reflect differences in health services and settings in which previous studies were conducted, in addition to the relatively small samples.

Consistent with previous literature [2, 9, 10, 11, 14, 15, 17], this study found that presence and severity of post-stroke lateropulsion was associated with longer rehabilitation LOS. In this study, average LOS (adjusted for calendar year, admission mRS, FIM, and inattention) in those with severe lateropulsion was almost nine days longer than that of those with no lateropulsion. With the exception of the studies by Babyar et al. [14, 15], this difference in LOS is lower than that reported in other studies; however these studies used different participant populations, accounted for different patient factors, and utilised different measures of lateropulsion than the present study. Of note, this study showed average functional change to be much lower in those with severe lateropulsion (FIM change of 10.7 points) versus those without lateropulsion (FIM change of 25.9 points). It is possible that the finding of reduced functional change in those with severe lateropulsion is related to the relatively low increase in rehabilitation LOS for participants in this study. It is hypothesised that if rehabilitation duration were further extended for those with severe lateropulsion, the discrepancies in functional change between those with severe lateropulsion and no lateropulsion may have been reduced. It was also noted that in this study, mean FIM change at all levels of the 4PPS was greater than the MDC for this measure, indicating that these FIM improvements likely represented true change. FIM change in those with mild and moderate lateropulsion was greater than the MCID for the FIM, indicating that these improvements were likely to be clinically meaningful, resulting in a change in patient care requirements [23]. Additional studies are needed to confirm whether a further protracted LOS for those with severe lateropulsion after stroke will result in clinically meaningful change in this cohort.

In contrast to Babyar et al. [17],[15], this study did not show an association between side of stroke and amount of functional recovery. Consistent with data from previous studies [10, 14, 17], this study found FIM efficiency in those with severe lateropulsion on admission to be less than half that of those with no lateropulsion. Future studies are needed to confirm whether extending rehabilitation duration for this cohort would result in a greater increase in functional change that leads to higher levels of long-term independence.

There is a lack of agreement between prior studies about the association between post-stroke lateropulsion and discharge destination. Babyar et al. [17], Krewer et al. [10], and Pedersen et al. [2] found a reduced likelihood of discharge home in those with lateropulsion, while Danells et al. [11] and Clark et al. [9] reported only slightly greater numbers of participants without lateropulsion to be discharged home, with non-significant differences between groups. In the present study, severe lateropulsion on admission was associated with reduced likelihood of discharge home. These findings agree with previous studies that have indicated that presence and severity of lateropulsion post stroke, independent of post-stroke disability, is associated with reduced likelihood of discharge home after rehabilitation [2, 10, 17]. It is possible that with an opportunity for longer rehabilitation LOS, and therefore possibility of greater functional improvement, the likelihood of discharge home in this cohort with more severe lateropulsion may increase. This would require adjustment of current stroke rehabilitation funding models to account for both stroke post-stroke disability and the extent of pushing behaviour at admission.

Limitations

This study was the first to use the 4PPS to examine outcomes associated with post-stroke lateropulsion. It was noted that three participants scored zero (no lateropulsion) on admission but one (mild lateropulsion) on discharge. As mild lateropulsion measured by the 4PPS is only apparent in standing or walking, it may not be detected on admission, and only become apparent as a stroke survivor improves. Although an advantage of the 4PPS is that it is very quick to administer, it is likely that the BLS, which has 17 levels and very clear scoring instructions, would be more sensitive in detecting mild lateropulsion and documenting smaller improvements as an affected person recovers. Clinically, the 4PPS may be sufficient in detecting meaningful change, as improvement of one level on the 4PPS is likely to result in functional change (eg. moving from 4PPS of three to two usually indicates attainment of independent sitting balance, which may permit less dependent mobility). Further investigation is required to assess the sensitivity of the 4PPS in detecting mild lateropulsion.

As this study used retrospective data from a departmental database, variables included for analysis were limited to those included in the database. Stroke severity measures were not included in the database, but the mRS, a measure of post-stroke disability, and Oxford Stroke Classification, were available and were used in this study as indicators of stroke severity. Prior studies [28, 29, 30, 31] have found that continence and carer availability are important predictors of returning home after stroke. Although the database captured presence of a carer prior to the stroke and on discharge from rehabilitation, availability of a carer is not recorded, which may have confounded findings for discharge destination. Continence was not included in the database so could not be included in this analysis. There were no set criteria to define readiness for discharge from the SRU. Discharge is usually dependent on patient and carer safety, provision of carer training where required, environmental set-up, and access to ongoing rehabilitation, as indicated. These factors were not included in the database and could not be included in the analysis. Prior studies [14, 15] have also found associations between recovery of lateropulsion and presence of sensory / proprioceptive impairment, which was not recorded in the database. Acute stroke management, for instance use of thrombolysis and thrombectomy, was also not recorded in the database, consequently associations between these interventions and lateropulsion recovery could not be investigated. Longer acute LOS was noted in this study to be related to poorer recovery of both lateropulsion and function. The reason for longer acute LOS is not recorded, but it is possible that stroke severity and post stroke complications, which can contribute to poorer recovery, were a factor in longer acute LOS. However, limited availability of rehabilitation beds, resulting in a longer time awaiting transfer to rehabilitation, would also contribute to a longer acute LOS. It is possible that this delay in commencing rehabilitation also contributed to poorer recovery in this cohort of participants.

In conclusion, this study included the largest published cohort to date of stroke survivors with lateropulsion, and explored a range of associations with lateropulsion and stroke recovery. Independent of stroke-related disability, post-stroke lateropulsion is associated with longer rehabilitation LOS, reduced functional recovery and reduced likelihood of discharge home. Stroke survivors with lateropulsion can make significant functional improvements with rehabilitation. A protracted period of rehabilitation for those with post-stroke lateropulsion, leading to increased functional independence, may increase likelihood of discharge home, and/or optimise their functional level on discharge, even if they are not able to return home.

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Table 1. Difference in LOS and functional change between those with and without lateropulsion, reported in prior studies.

Study	**LOS difference**	**Functional change**
Krewer et al.[10]	21 days (Mean rehabilitation LOS: 12±6 weeks for participants with lateropulsion versus 9±6 weeks for participants with lateropulsion and 11±7 weeks for participants without lateropulsion unable to stand unsupported)	Barthel Index efficiency for participants with lateropulsion: mean 1.9±2.7, and for participants without: mean 4.6±4, or participants without lateropulsion unable to stand unsupported: mean 3.6±3.3
Danells et al.[11]	32 days (Mean total hospital LOS for participants with lateropulsion: 89 days versus 57 days for participants without lateropulsion)	Functional Independence Measure (FIM): 38.8 points in those with lateropulsion, 36.6 points in those without
Clark et al.[9]	30 days (Mean rehabilitation LOS for participants with lateropulsion: 58.9±24 days versus 29.3±17.2 days for participants without lateropulsion)	(not reported)
Pedersen et al.[2]	38.8 days (Mean rehabilitation LOS for participants with lateropulsion: 72.7±31.2 days versus 33.9±26.5 days for those without lateropulsion)	Barthel Index (BI): 30.2 points in those with lateropulsion, 20 points in those without
Babyar et al. [16]	0.5 days (Mean rehabilitation LOS for participants with lateropulsion: 29.6±8.7 days versus 29.1±7.6 days for those without lateropulsion)	FIM: 23.2 points in those with lateropulsion, 31.6 points in those without

Table 2. Summary characteristics of study cohort stratified by 4PPS at admission. Chi-square and F-tests of equality were performed.

	Total		**4PPS at Admission**								
	N=1087		**0 (n=604)**		**1 (n=160)**		**2 (n=142)**		**3 (n=181)**		**p-value**
	N	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	
Age group											
65-69	156	14.4	83	13.7	21	13.1	25	17.6	27	14.9	
70-74	186	17.1	96	15.9	35	21.9	24	16.9	31	17.1	
75-79	223	20.5	107	17.7	38	23.8	35	24.6	43	23.8	0.284
80-84	237	21.8	138	22.8	31	19.4	27	19.0	41	22.7	
85-89	191	17.6	119	19.7	23	14.4	22	15.5	27	14.9	
90+	94	8.6	61	10.1	12	7.5	9	6.3	12	6.6	
Sex											
Female	524	48.2	303	50.2	75	46.9	63	44.4	83	45.9	0.516
Male	563	51.8	301	49.8	85	53.1	79	55.6	98	54.1	
Oxford Class											
LACS	203	18.8	129	21.5	36	22.5	26	18.4	12	6.7	
PACS	531	49.1	304	50.6	77	48.1	63	44.7	87	48.3	<0.001
POCS	185	17.1	124	20.6	29	18.1	20	14.2	12	6.7	
TACS	163	15.1	44	7.3	18	11.3	32	22.7	69	38.3	
Side of stroke											
Left	561	51.7	340	56.4	81	50.6	74	52.1	66	36.7	<0.001
Right	524	48.3	263	43.6	79	49.4	68	47.9	114	63.3	
Type of stroke											
Haemorrhage	211	19.4	95	15.7	29	18.1	29	20.4	58	32.0	<0.001
Infarct	876	80.6	509	84.3	131	81.9	113	79.6	123	68.0	
Inattention											
No	743	68.4	475	78.6	119	74.4	90	63.4	59	32.6	<0.001
Yes	344	31.6	129	21.4	41	25.6	52	36.6	122	67.4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Admission FIM	67.1	25.9	80.8	21.5	61.2	20.9	50.5	18.1	39.8	14.8	<0.001
Acute LOS	11.9	10.6	10.2	9.2	11.6	10.7	14.7	11.0	16.0	12.7	<0.001

Table 3. Adjusted* multivariable linear regression of the relative change in FIM from admission to discharge by admission 4PPS (n=1,080)

4PPS at admission	Relative change in FIM	95% CI	p-value	Adjusted mean change in FIM	95% CI
0	0	referent	-	25.9	24.5-27.1
1	-3.1	-5.7- -0.6	0.017	22.8	21.2 – 25.7
2	-3.0	-5.9- -0.1	0.044	23.0	21.2-26.1
3	-15.3	-18.3 - - 12.3	<0.001	10.7	8.9-13.8

*Model also included age, Oxford class, admission FIM, admission cognitive FIM, type of stroke and acute care LOS. Two participants had missing data for cognitive FIM, five participants had unknown Oxford class and were excluded.

Table 4. Size and direction of improvement in 4PPS for each level of admission 4PPS (n=483).

	Change in admission 4PPS by time of discharge								
	Improved by 3		**Improved by 2**		**Improved by 1**		**No change**		
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**Total**
Admission 4PPS									
1					111	69.4	49	30.6	160
2			70	49.3	50	35.2	22	15.5	142
3	34	18.8	46	25.4	56	30.9	45	24.9	181
Total	34	7.0	116	24.0	217	44.9	116	24.0	483

Table 5. Adjusted* negative binomial regression estimates of rehabilitation LOS for each level of the 4PPS (n=1,084).

4PPS at admission	**Adjusted IRR****	**95% CI**	**p-value**	**Predicted adjusted mean rehabilitation LOS**	**95% CI**
0	1.0	referent	-	27.0	25.7-28.4
1	1.2	1.1-1.3	<0.001	32.1	29.8-34.5
2	1.3	1.2-1.4	<0.001	35.4	32.7-38.1
3	1.3	1.2-1.5	<0.001	35.6	33.1-38.2

*Model also included calendar year, admission mRS, admission total FIM, and presence of inattention. Two participants had missing data for mRS and were excluded.

**IRR =Incidence rate ratio

Table 6. Adjusted* Poisson regression estimates of FIM efficiency for each level of the 4PPS (n=1,061).

4PPS at admission	Relative ratio FIM efficiency**	95% CI	p-value	Adjusted mean FIM unit increases per day	95% CI
0	1.0	referent	-	1.22	1.13 - 1.30
1	0.80	0.68-0.96	0.015	0.98	0.82 – 1.14
2	0.75	0.61-0.91	0.05	0.91	0.74 – 1.08
3	0.42	0.33-0.54	<0.001	0.52	0.40 – 0.64

*Model also included calendar year, age, Oxford classification and acute care LOS. Two participants had missing data for Oxford Classification were excluded.
**Incidence rate ratio

Figure 1. Box plot of median admission and discharge FIM scores stratified by admission 4PPS.