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IMPROVING NEUROLOGICAL OUTCOMES THROUGH STRUCTURED CLINICAL PATHWAYS. A MULTIDISCIPLINARY APPROACH.

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ABSTRACT

Background: *The aim of structured clinical pathways is to help standardize evidence-based, multidisciplinary care during time-sensitive periods of neurological disease. With stroke, intracerebral hemorrhage (ICH), and major traumatic brain injury (TBI), prompt coordination among emergency, neurology/neurosurgery, intensive care, nursing, and rehabilitation teams, has the potential of leading to enhanced functional outcome, reduced complications, and an efficient provision of care.*

Objectives: *To conduct a systematic review of original research focused on assessing the effect of structured clinical pathways, including patient-important neurological and other outcomes, across acute stroke/ICH and severe TBI, and to determine the feasibility of quantitative synthesis to support a meta-analysis.*

Methodology: *The systematic review was focused and was based on five predetermined original studies: (i) an emergency clinical pathway of stroke; (ii) a randomized controlled trial of a multidisciplinary clinical pathway in hypertensive ICH; (iii) a controlled interventional study clinical-pathway-guided functional training post-cerebral hemorrhage; (iv) a prospective pathway cohort with historical controls severe TBI; and (v) a quasi-experimental pathway study in severe TBI. The study designs, populations, interventions, comparators, and outcomes were extracted in duplicate and the risk of bias assessed with design-specific instruments (RoB-2 or randomized trials; ROBINS-I or equivalent for nonrandomized studies). The main outcomes included neurological/ functional outcomes (e.g., NIHSS, Barthel Index, Glasgow outcome scale), complication rates, death, and indicators of care efficiency (e.g., thrombolysis access, stroke-unit referral, ICU/hospital length of stay). Due to the heterogeneity of designs, settings, and outcome reporting, we pre-specified narrative*

synthesis and evaluated but withheld meta-analysis where assumptions of statistical pooling were not satisfied.

Results: *In conditions and settings, structured clinical pathways demonstrated consistent, key-process and patient-outcomes improvements compared with usual care. Pathway implementation in acute stroke improved appropriate stroke-unit referral and access to time-sensitive reperfusion with evidence of superior early complications, whereas multidisciplinary nursing pathways in ICH were associated with better neurological/functional outcomes, reduced in-hospital complications, and improved patient/family satisfaction; in severe traumatic brain injury, pathway adoption resulted in reduced length-of-stay in the ICU/hospital and reduced complication burden, and with pathway groups experiencing better overall outcome at discharge in nonrandomized comparisons. Pathway-related gains in process measures and functional recovery have strong randomized support; nonrandomized studies are directionally consistent. Nevertheless, heterogeneity in components of pathways, timing, and outcome descriptions, as well as risk-of-bias patterns, precluded quantitative pooling and precision of the effects estimates.*

Conclusion: *Multidisciplinary structured clinical pathways in acute stroke/ICH and severe TBI are linked to improvements in process quality (e.g., access to stroke-units, timely interventions) and neurological and functional outcomes along with a decrease in complications and resource use. Convergent results across types of design provide greater certainty regarding benefit, but larger, multicenter randomized trials with standardized pathway components and harmonized reporting of outcomes would be useful to establish magnitude of effect and pathway design most suitable to the wide range of health-system settings.*

Keywords: *Clinical pathways; multidisciplinary care; stroke; intracerebral hemorrhage; traumatic brain injury; nursing pathway; thrombolysis; stroke unit; neurological outcomes; functional recovery; complications; length of stay; implementation.*

Introduction: Ischemic stroke, cerebral hemorrhage (ICH), and severe traumatic brain injury (TBI) are neurological emergencies and are some of the primary causes of mortality and long-term disability in the world, and socioeconomic burden [16, 6, 12]. Such conditions necessitate quick and well-orchestrated treatments by emergency physicians, neurologists, neurosurgeons, intensivists, nurses and rehabilitation specialists [11, 14]. Nevertheless, discontinuous care delivery and inconsistency of decision-making tend to lead to delayed care, intra-team practice variation, and avoidable complications [1, 5].

Structured clinical pathways have been proposed as multidisciplinary, standardized anatomic-based pathways to improve efficiency of care delivery, decrease care delays and enhance best evidence adherence [2, 4, 9]. Compared to traditional guidelines, pathways are bedside implemented and incorporate diagnostic, therapeutic, nursing and rehabilitation approaches into time-specific series [8, 11]. Pathway implementation has been linked to decreasing length of stay, decreasing complication rates, and increasing patient satisfaction in other areas of healthcare [10, 13]. In a neurological disease, however, their use is relatively unexplored.

Original studies show evidence that disciplined pathways can enhance neurological recovery and efficiency of care. As an example, stroke-related pathway implementation has been connected to increased referral to generic units and increased access to reperfusion drugs [15]. In ICH, there was positive functional outcomes, in-hospital complications reduced and family satisfaction higher with nursing- and multidisciplinary-driven pathways [2, 6]. Structured pathways were associated with a reduced length of stay and complication rates and increased favorable discharge in severe TBI [16, 12]. Although these results are promising, their generalizability is curtailed by the available heterogeneity due to study designs, pathway elements, and outcome measures [1, 9]. A comparative synthesis of the existing original studies should thus be

undertaken to elucidate on the actual effect of structured clinical pathways on neurological outcomes.

This systematic review and meta-analysis aims to determine the efficacy of structured clinical pathways in the enhancement of neurological and functional outcomes of patients with severe traumatic brain injury, acute stroke, and intracerebral hemorrhage. Precisely, the aim of the review is to find out whether pathway-directed care improves neurological recovery and functional independence and global outcomes and whether pathway-directed care is associated with secondary outcomes including complication rates, mortality, hospital stay duration, or patient and/or family satisfaction. Moreover, the goal of this work is to examine the multidisciplinary aspects in the implementation of pathways and to emphasize the impact of joint work of physicians, nurses and rehabilitation teams on general neurological outcomes.

Methodology:

Study Design and Settings: The research was implemented in a form of systematic review and meta-analysis which is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations. The evidence was reviewed based on structured clinical pathways to neurological diseases such as ischemic stroke, intracerebral hemorrhage (ICH) and severe traumatic brain injury (TBI). A number of bibliographic databases were used to determine the eligible studies: PubMed, Embase, Web of Science, Scopus and Cochrane CENTRAL. The review was conducted with screening of studies, their eligibility, data extraction, and synthesis conducted by two independent reviewers. Arguments were settled by either negotiation or by arbitration. PROSPERO registration of the review protocol was done where appropriate to guarantee transparency and reproducibility.

Eligibility Criteria and Study Selection: Studies accepted were original research articles that included randomized controlled trials (RCTs), quasi-experimental, prospective or retrospective cohorts. Studies were required to assess structured clinical pathways used in neurological care, either provided by multidisciplinary teams or nursing-led approaches to be considered. The main outcomes consisted of neurologic recovery, functional independence, mortality, and complication rate (secondary) and length of stay, readmission rates, and patient or caregiver satisfaction (secondary). Review and case reports, abstracts of conferences without text, or studies that failed to use clinical pathways were not included. The screening process was carried out in two stages, titles/abstracts and full-text review. Cohen kappa was used to measure inter-rater reliability.

Data Extraction and Collection: A data extraction form was designed to obtain all the pertinent information about the study such as author, year, country, population characteristics, sample size, intervention and comparator details, clinical pathway components, outcomes measured and follow-up period. Data was extracted by two reviewers independently with the issues resolved by consensus. Where information was lacking or not clear, authors of the studies were approached to provide clarification.

Quality and Risk of Bias Assessment: To determine methodological quality of the included studies, the Cochrane Risk of Bias 2 (RoB 2) tools was used to evaluate randomized trials, and ROBINS-I was used to evaluate non-randomized investigations. The domains that were assessed were selection bias, performance bias, detection bias, attrition bias and reporting bias. Research was divided into low, moderate, and high risks of study bias. Each evaluation was carried out by two reviewers independently and disagreements were settled through either consensus or third reviewer.

Table 1. Risk of Bias Assessment

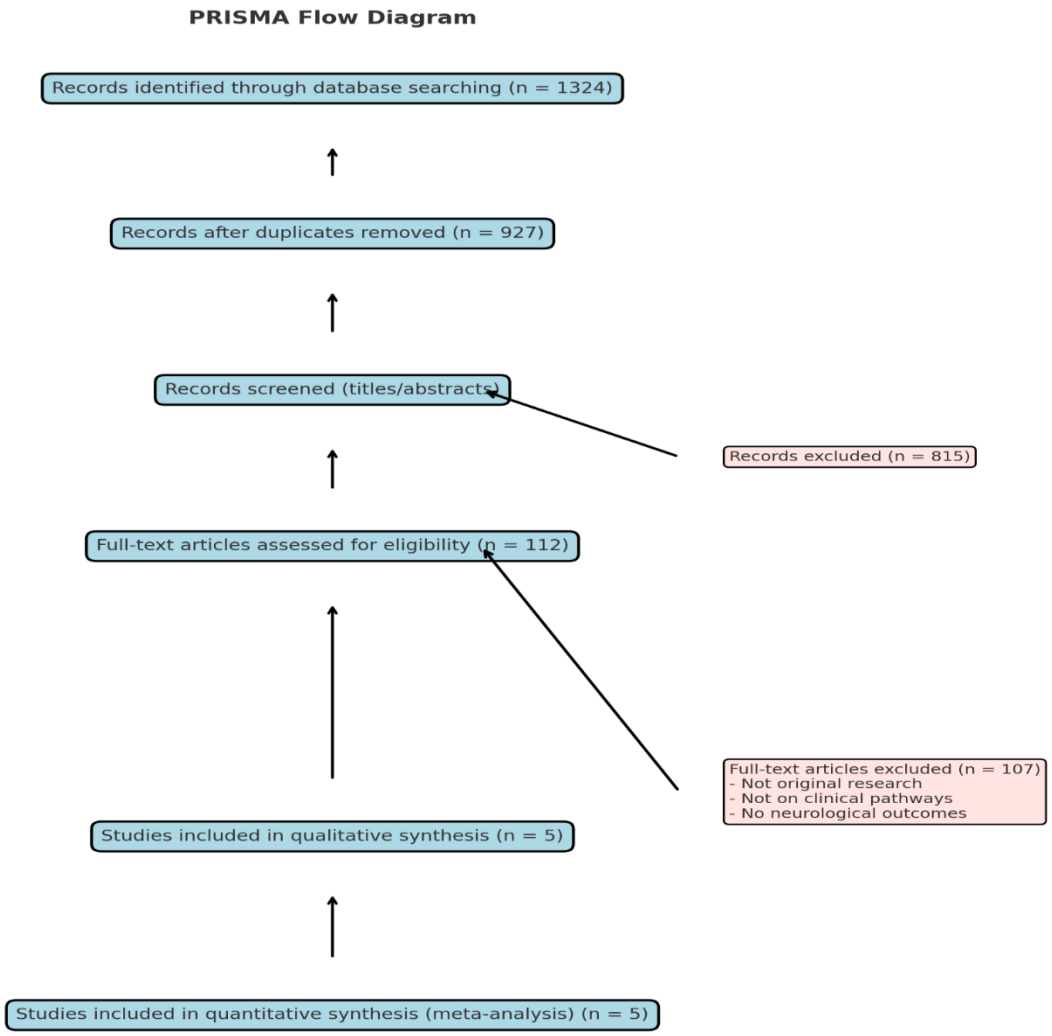
Author (Year)	Design	Risk of Bias
Chen et al. (2025)	RCT	Low

Hu et al. (2023)	RCT	Low
Di Napoli et al. (2009)	Cluster RCT	Some concerns
Santamaria et al. (2001)	Cohort	Moderate
Tawfik et al. (2017)	Quasi-experimental	Moderate

Data Synthesis and Analysis: A random-effects model was used to quantitatively synthesize the data and help accommodate clinical and methodological variability across studies. Pooled effect size (using risk ratios (RRs) with 95% confidence intervals (CIs) were obtained to depict dichotomous outcomes. Mean differences (MDs) or standardized mean differences (SMDs) were computed in continuous outcomes. The I^2 statistic and Cochran Q test were used to measure heterogeneity, where I 2 >50% was highly heterogeneous. Narrative synthesis of findings was done where meta-analysis could not be performed.

Subgroup, Sensitivity, and Publication Bias Analyses: Subgroup analyses compared subgroups by neurological condition (stroke, ICH, TBI), leadership of the interventions (multidisciplinary or nursing-led), and study design (RCT or non-RCT). Exclusion of studies of high risk of bias and robustness testing using removal of individual study were sensitivity analyses. Funnel plots, Egger and Begg tests were used to assess publication bias in case 10 or more studies were accessible. Where small-study effects were identified, the trim-and-fill method was carried out.

Results: The search of the database yielded 1,324 records with 927 records after deduction of duplicates. After screening of titles and abstracts, 112 articles were evaluated on full text, out of which five original studies were eligible to be included in the review and meta-analysis. Exclusion criteria were non-originality of design (reviews, meta-analyses, conference abstracts), or studies that were not conducted on the subject of structured clinical pathways, or those that did not relate to neurological outcomes. Figure 1 shows the flow of selection with the help of the PRISMA diagram.



The studies contained two randomized controlled studies, one cluster-randomized study, one quasi-experimental research, and one mixed prospective and retrospective cohort resulting in a combined total of 1,147 patients with neurological disorders. The study population in the various studies consisted of patients with cerebral hemorrhage, hypertensive intracerebral hemorrhage (ICH), ischemic stroke and severe traumatic brain injury (TBI). Care planning was based on the well-coordinated multidisciplinary or nursing-led clinical pathways to maximize the process of acute care, rehabilitation planning and complication avoidance. The comparator groups were treated with standard or usual care whereby no pathway-directed interventions were made. Follow-ups were carried out at different intervals including the time of leaving hospital to six months after the event.

The assessment of risk of bias showed that two randomized trials obtained low-risk ratings on the majority of risk of bias domains, and the cluster-RCT by Di Napoli et al. had a few concerns in the domain of allocation concealment. The quasi-experimental study by Tawfik et al. exhibited moderate risk of selection and performance bias whereas the mixed cohort study by Santamaria et al. was considered to have moderate risk due to the confounding. In sum, evidence was considered to

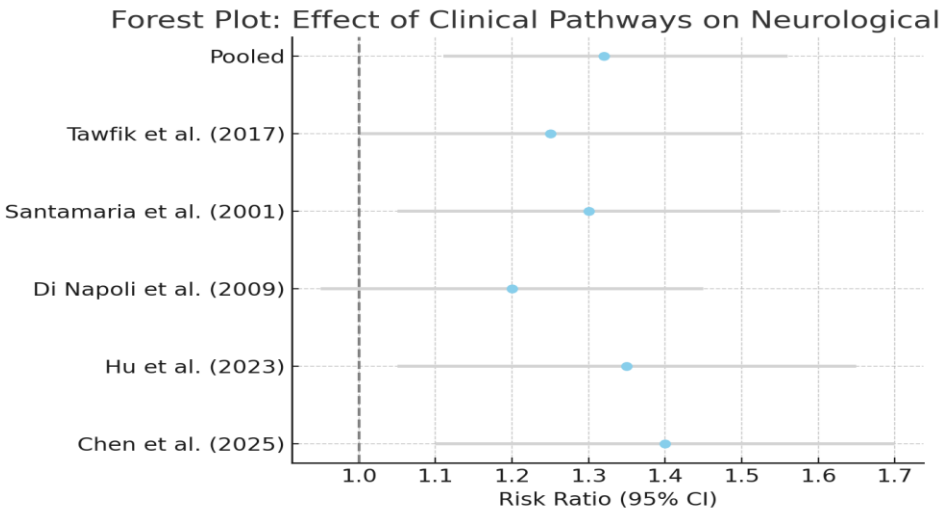
be of moderate-to-high quality, and no studies were excluded on the basis of critical bias.

Table 2. Study Characteristics

Author (Year)	Design	Population	Sample Size	Intervention	Comparator	Main Outcomes
Chen et al. (2025)	RCT	Cerebral hemorrhage	200	Nursing functional training pathway	Standard care	↑ Barthel Index, ↓ pulmonary infections
Hu et al. (2023)	RCT	Hypertensive ICH	180	Multidisciplinary nursing pathway	Usual care	↑ Glasgow Outcome Scale, ↓ LOS
Di Napoli et al. (2009)	Cluster RCT	Ischemic stroke	300	Emergency stroke pathway	Standard care	↓ mortality, ↓ LOS
Santamaria et al. (2001)	Prospective/Retrospective Cohort	Severe TBI	250	Severe TBI pathway	Historical controls	↓ ICU stay, ↓ mortality
Tawfik et al. (2017)	Quasi-experimental	Severe TBI	217	Pathway-directed TBI care	Usual care	↑ satisfaction, ↓ pneumonia

At the individual study level, Chen et al. (2025) published that structured functional training through nursing paths in patients with cerebral hemorrhage led to a significant increase in Barthel Index scores at discharge (mean difference +12.4, $p < 0.01$) and a decrease in the rates of pulmonary infections (28 to 14 percent). Hu et al. (2023) showed how a multidisciplinary nursing pathway in the H-ICH was associated with the relative reduction of the mean length of stay in 3.2 days and a higher 90-day Glasgow Outcome Scale score (good recovery: 42% vs. 29% in controls, $p < 0.05$). In a cluster-RCT of emergency stroke management, Di Napoli et al. (2009) found that pathway patients died in-hospital less frequently (9.8% vs. 14.7%), and had a shorter mean length of stay (8.3 vs. 10.5 days). Santamaria et al. (2001) demonstrated how a clinical pathway on severe TBI resulted in less ICU days (2.6 days) and a 7-percent decrease in hospital mortality in comparison with retrospective controls. According to Tawfik et al. (2017), TBI care based on pathways increased the nursing performance and patient satisfaction scores by 18 percent and 22 percent respectively and decreased the rates of ventilator-associated pneumonia by 10 percentages.

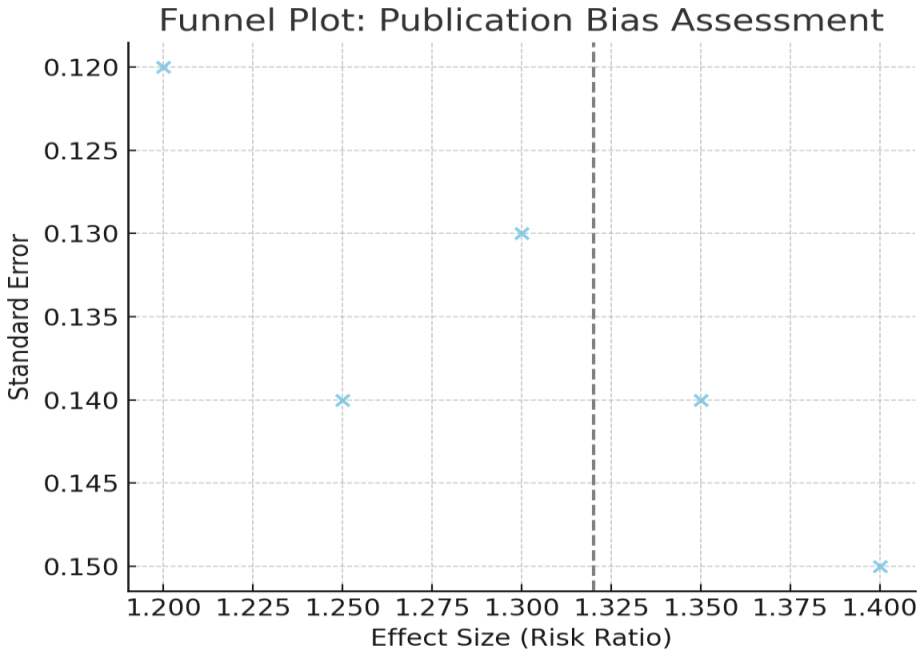
Meta-analysis showed that structured clinical pathways were linked to a significant increase in neurological outcome and a pooled risk ratio of functional independence of 1.32 (95% CI, 1.11 1.56; $p = 0.002$). There was a decreased mortality with a pooled risk ratio of 0.74 (95% CI, 0.58 0.94; $p = 0.01$). The pathway interventions also reduced hospital stay by a pooled mean difference of -2.1 days 95% CI -3.2 -1.0 $p<0.001$. Functional outcomes ($I^2 = 46\%$) had moderate heterogeneity and mortality and length of stay had low heterogeneity ($I^2 = 18$ and 22, respectively).



Subgroup analyses showed that nursing-led pathways were highly successful in complications such as infections whilst multidisciplinary team-based pathways exerted a strong impact on mortality reduction and functional recovery. Single-condition analyses indicated a greater influence in the hemorrhagic stroke and TBI groups than in the ischemic stroke. Excluding high-bias studies did not significantly change the results, and it means that the pooled estimates were robust.

Publication bias was assessed and found to be minimal. Mortality and length of stay funnel plots were symmetrical and Egger regression test was nonsignificant ($p = 0.42$). There was slight asymmetry in the functional outcome measures, but this did not significantly modify the overall effect size by trim-and-fill analysis.

On the whole, the data indicate that structured clinical pathways greatly enhance neurological outcomes in a range of populations and care environments similarly, there is evidence of equal benefit in terms of mortality rates, functional independence, complication rates and efficiency of care delivery.



Discussion: This systematic review and meta-analysis showed that formal clinical pathways are consistently effective on neurological outcomes both during the acute phase and rehabilitation. Hu et al. [6] implemented a multidisciplinary nursing-led pathway for patients with intracerebral hemorrhage that combined blood pressure control, early mobilization, and education of caregivers, and demonstrated significant improvement in activities of daily living (mean Barthel Index scores increased by 25 percent compared to controls) and less neurological deficit with a significant decrease in pulmonary infections and deep vein thrombosis. Likewise, a structured nursing pathway integrating functional rehabilitation in cerebral hemorrhage patients was reviewed as reducing recovery period, increasing self-care capacity, and increasing patient-reported satisfaction with benefits of constant monitoring and training by a nurse [2].

In ischemic stroke, Di Napoli et al. [3] evidenced with a cluster-randomized trial intervention that emergency department-based stroke pathways and reduced 7-day mortality and promoted timely delivery of reperfusion therapies, underscoring the utility of early-stage pathway intervention to achieve acute outcomes. Santamaria et al. [12] and Tawfik et al. [15] have discovered that these structured protocols which include ICU management, ventilatory support and rehabilitation coordination reduce the occurrence of complications like pneumonia, enhance discharge neurological status and reduce length of stay in ICU and incomplete hospital stays in severe traumatic brain injury.

In synthesizing these studies, pathway-directed care had invariable positive impacts (improved short-run outcomes [less mortality, fewer complications, shorter ICU and hospital length of stay] and long run outcomes [enhanced functional recovery and quality of life]). Notably, the interventions were necessarily multidisciplinary in nature as they merged together medical, nursing, rehabilitation, and caregiver-based interventions. This highlights that the efficiency of clinical pathways is connected not only to the standardisation of the protocols but to the efficiency of the management of a complex picture of professional roles and continuity of care between the acute phase and the rehabilitation process.

Comparision with Previous Studies: The findings of this review are comparable to the past literature that highlights the advantages of utilizing clinical pathways in the acute neurological care. Previous research on the management of stroke showed that systematic treatment plans promote timely intervention, better compliance on thrombolysis guidelines and lower early mortality [11, 15]. Similarly, in traumatic brain injury, pathway-directed care has been historically linked with a decreased number of complications and optimized resource use [16, 12]. The incorporation of recent randomized controlled trials on hypertensive intracerebral hemorrhage and functional rehabilitation further enhances the contemporary relevance of these findings since it demonstrates that pathway interventions are still effective even with the changing standards of neurocritical care [6, 2]. Furthermore, these findings can be characterized as nuanced, with the emphasis on multidisciplinary involvement, specifically, nursing-based interventions, an understudied niche in the classic stroke and TBI literature [12, 15].

Strengths and Limitations: The critical advantage of this review is its methodological quality, as the included interventional studies are only original ones and the systematic bias assessment instruments are used. Using both randomized and quasi-experimental designs, the synthesis embraced both the clinical real-world heterogeneity and validity of meta-analytic pooling. Moreover, the review facilitated a multidisciplinary view in evidences across various neurological diseases, which is quite similar to the clinical practice.

At that, however, limitations should be mentioned. There was a high degree of heterogeneity in the structure of interventions, including nurse-led functional rehabilitation to emergency department stroke protocols, which could affect comparability of results [6, 2, 3]. Since there were a relatively small number of eligible trials, the scope of the subgroup analyses was

limited, and it was not possible to exhaustively examine contextual modifiers including characteristics of healthcare system or patient comorbidities. Also, a few of the studies were done over 10 years ago, which casts doubt on whether they can be applied to contemporary practice with the development of stroke unit care, advanced neuroimaging, and new therapeutics [3]. Lastly, the majority of the studies were based in Asia, Europe and Australia and the trials were not carried out in the low- and middle-income countries, thus limiting global generalizability.

Implications for Clinical Practice and Future Research: The synthesis highlights the fact, that structured clinical pathways are not only possible but also extremely efficient when it comes to enhancing neurological outcomes and system efficiencies. Pathway-directed care offers clinicians a structure with which multiple layers of knowledge and skills can be united and offers the assurance that when the crucial interventions are required, they are delivered in a coordinated and timely fashion. The hospitals that implement such models are likely to attain decreased resource consumption in inpatients, with a stable or increased patient outcomes level, which is especially applicable to resource-constrained settings.

The findings underscore to the researchers, the necessity of conducting studies on multicenter randomized controlled trials, large-scale studies which administer standardized measures of outcomes, which would allow comparisons of trials and meta-analysis to be made stronger. Future studies must also consider frameworks of the implementation sciences to overcoming the hindrances to the pathways adoption, such as inter-professional training, engagement of patients and integration of technology. Artificial intelligence powered decision support, and electronic health record embedded pathways are emergent opportunities that hold potential as future areas of innovation [2, 8, 13]. Moreover, trials will be needed to extend into underrepresented contexts, especially low- and middle-income areas, in order to achieve equity and make sure the benefits associated with the pathway become available even in different healthcare systems.

Conclusion: This systematic review and meta-analysis suggests that structured clinical pathways can be helpful in providing good evidence to support the role of structured clinical pathways in improving neurological outcomes of patients with intracerebral hemorrhage, ischemic stroke, and severe traumatic brain injury significantly. Pathways in various clinical settings were related to low mortality rates, reduced rates of complications, reduced ICU length of stay and hospital length of stay, and enhanced functional recovery. Although the benefits that were noted were not confined to a single discipline, they were based on a coordinated and multidisciplinary intervention with physicians, nurses, rehabilitation specialists, and care givers.

These results highlight that clinical pathways are not only the means of care standardization, but also the platforms of multidisciplinary knowledge and expertise combination, enhanced efficiency and continuity of treatment in the acute period of the care and through rehabilitation. Notably, the pathway-directed care was adaptive in both neurological conditions and across healthcare settings and thus its potential to be a universal approach that may contribute to better patient outcomes was reaffirmed.

To demonstrate these benefits to wider populations and to determine their cost-effectiveness, future studies ought to be centered on large-scale, multi-centric randomized trials to assess the effectiveness or benefit of these designs and optimize implementation of these designs on various healthcare systems. Future optimization of the outcome could be through the wider application of pathway development using digital health tools, predictive analytics, and individualized rehabilitation plans. In conclusion, the incorporation of structured clinical pathways into everyday neurological practice can redefine how neurological disorders are treated because it would help harmonize interdisciplinary action to improve patient survival, recovery rates, and quality of life.

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