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Spinal Alignment/Deformity

Relationship between spinal alignment and functional disability after thoracolumbar spinal fractures: A systematic review

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ABSTRACT

Background: Thoracolumbar spinal fractures (TLSF) can cause pain, neurological deficits, and functional disability. Operative treatments aim to preserve neurological function, improve functional status, and restore spinal alignment and stability. In this review, we evaluate the relationship between spinal alignment and functional impairment in patients with TLSF.
Methods: We performed a systematic review in accordance with the PRISMA guidelines to identify full-text articles that evaluate the correlation between spinal alignment and functional outcomes of TLSF. The artificial intelligence software Rayyan assisted the screening process. Functional outcomes referred to activity/disability, quality of life, and pain scores, as well as return to work metrics. Radiological assessments included were vertebral compression angle, Cobb and Gardner angles, sagittal vertical axis, pelvic incidence, and pelvic tilt. Statistical analyses were performed for the data provided by articles using the SPSS v24.
Results: Of 1,616 articles reviewed, 6 were included for final analysis. Only 1 study primarily addressed the effects of spinopelvic parameters and functional outcomes. Four studies correlated Cobb angles with functional outcome, while 3 others compared vertebral compression angles with functional outcomes. Outcomes were assessed using work status or a combination of VAS pain and spine score, ODI, SF-36, and RMDQ-24. Neither the analysis done within the articles, nor the one made with the raw data provided by them, showed a significant correlation between the radiological measurements assessed at time of injury and final functional outcomes.
Conclusions: A correlation between the assessed spinal radiological measurements assessed with the functional outcomes of TLSF was not found in this review. Further well-designed prospective studies are necessary to evaluate spinal alignment measurements in TLSF with functional outcomes.

Background

Traumatic spinal injury comprises injuries to the spinal cord, nerve roots, vertebrae, ligaments, or intervertebral disks of the spinal column [1]. Annual incidence ranges from 30 to 50/100,000 people worldwide. These injuries typically affect males and are often the result of blunt trauma such as in motor vehicle collisions and falls [2,3].

Spinal fractures are a common consequence of blunt trauma, with an estimated incidence of 6.9% in the thoracolumbar region [4]. Around 25.6% of spinal injuries produce neurologic deficits, which may lead to physical, work, and social impairments [5]. These impairments often result in loss of independence and increased morbidity and mortality. The resulting estimated national financial burden is approximately $1.1-4.6 million dollars per patient over the course of his/her lifetime [6,7].

Treatment in the acute setting involves conservative (e.g., use of braces) or surgical measures, aiming at preserving neurological function and reestablishing normal or near normal spinal alignment [8]. The latter is commonly assessed with regular imaging techniques (e.g., plain radiographs, computed tomography), which allows the determination of multiple spinal parameters described in the literature (e.g., vertebral compression angle [VCA], Cobb angle, Gardner angle, pelvic incidence [PI], lumbar lordosis [LL], thoracic kyphosis [TK], etc) [9,10]. Unsuccessful treatment may lead to spinal malalignment, delayed neurologic deficit, chronic pain, and spinal deformity [11,12].

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Table 1
Inclusion and exclusion criteria for paper selection.

Inclusion criteria	Exclusion criteria
- Human studies; AND - Clinical series investigating traumatic thoracolumbar fractures only; AND - Objectively analyzed initial spine angles; AND - Provided detailed angle measurement method; AND - Objectively analyzed functional outcomes; AND - written in English language; AND - Full-text available; AND - Published in peer-reviewed journal.	- Did not correlate initial angles to functional outcomes and not provided enough data for analysis; OR - Pathological fractures (e.g., neoplasia, osteoporotic); OR - Initial angles obtained after 2 weeks of trauma.

Considering the importance of spinal alignment for treatment of degenerative conditions [13,14], the aim of the present study is to evaluate the relationship between spinal alignment parameters, long-term quality of life (QoL), and functionality outcomes in patients with thoracolumbar spine fractures (TLSF).

Methods

A systematic review was performed, aiming at identifying and extracting data from published work on functional outcomes after traumatic TLSF. A comprehensive literature search was performed on the PubMed, Scopus, and Web of Science databases—the detailed information on the search method, including search queries used, is shown on supplemental material (**Supplementary 1**). A manual search on the references of included papers was also performed. All publications found were screened independently by 2 investigators (RAAA and FCO), who were blinded to each other's decisions, using the artificial intelligence-based software Rayyan (available on https://new.rayyan.ai/) [15]. Under the PRISMA 2020 guideline, inclusion and exclusion criteria (Table 1) were applied to the studies found [16]. Of note, papers were also included if they provided individual data for their cohort that allowed statistics to be drawn. The main inclusion criteria were human clinical studies of TLSF who correlated spinal alignment (measured using objective and detailed measurement method) with functional outcomes, excluding cervical spine trauma and nontraumatic fractures.

Functional outcomes referred to activity/disability scores (e.g., ODI, RMDQ-24), QoL scores (e.g., SF-36) [17], pain scores (e.g., VAS pain, VAS spine score, Denis pain scale), and return to work scales (e.g., Denis work scale). Angles measured around the time of trauma (up to 2 weeks) were considered measurements of interest for this analysis and are referred to as "initial angles". In cases treated with surgery, the pre-

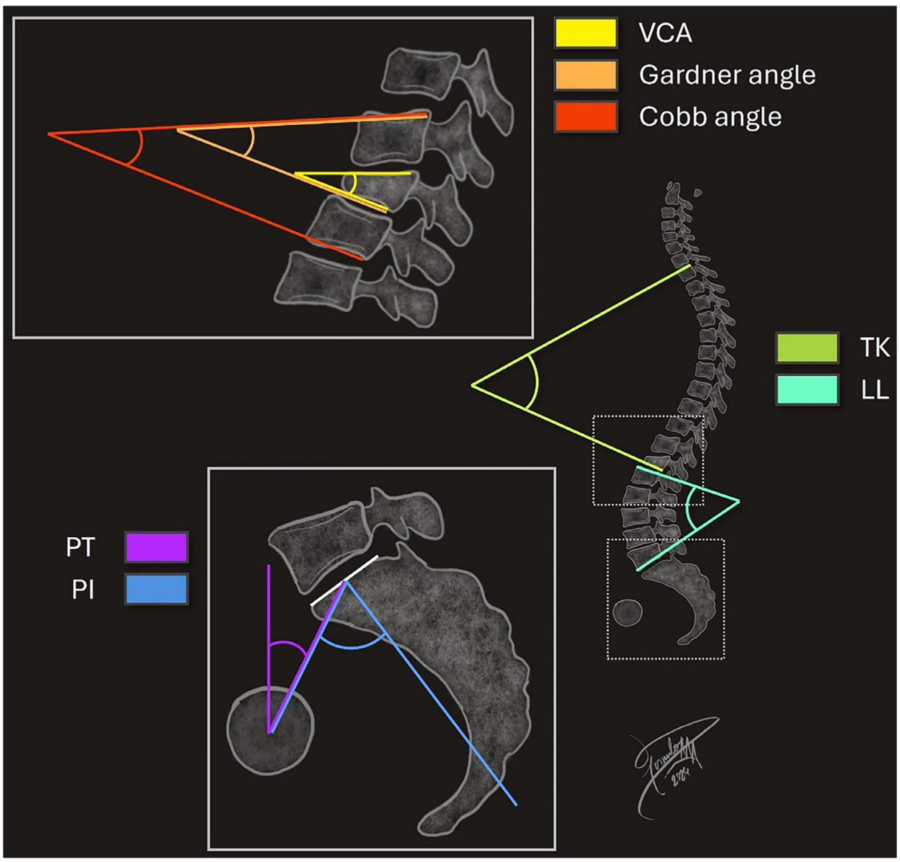

Fig. 1. Illustration showing the angles of interest for this study and the methods for their measurement. Due to variations in nomenclature, and for standardization purpose, angles found were subsequently categorized into the following angles (according to their original description): Gardner angle, Cobb angle, vertebral compression angle (VCA), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), and pelvic tilt (PT). The last 2 angles (PI and PT) use the midportion of the S1 superior endplate and the femoral head in their measurement. The sagittal index is calculated as the normal kyphotic angle subtracted from the VCA [36].

operative and immediate postoperative angles were considered. Examples of the most common spinal alignment measurements were: Cobb angle, Gardner angle, sagittal index (SI), PI, and PT [18-20]. As nomenclature varied among literature, we categorized the measurements found according to a standardized classification based on their description (Figure 1).

Statistical analyses were performed for the data provided by articles, as previously mentioned, using the SPSS v24 (IBM corp., Armonk, NY, USA). Pearson's correlation was used to compare 2 quantitative variables, such as initial angles vs. pain score. Logistic regression analysis was used to determine the association between initial angles and binominal/multinominal dependent variables.

Results

Article search results

In total, 1,616 articles were found and went through the screening process. The PRISMA flowchart showing the selection process is shown in Figure 2. At the end, only 6 papers fulfilled the inclusion and exclusion criteria. Table 2 shows the summarized data for these papers, with findings and levels of evidence.

Literature data

Only 1 paper primarily addressed the effects of spinopelvic parameters/sagittal vertical axis and final outcomes.

Joaquim et al. [20] investigated the SF-36, ODI, and work status of neurologically intact patients with AO Spine type A fractures of the thoracolumbar spine treated conservatively. Twenty-two patients (mean age, 47.1 years; 17 males) with 33 fractures were included. L1 was the most injured level and AO Spine type A1 was the most frequent fracture. At last follow-up (mean time of 27.8 months), mean ODI was 24.4% (range, 4%-58%) and mean SF-36 was 49.59 (range, 23-82.25) and 63.28 (range, 14.75-94.25) for the physical health and mental health scores, respectively. Additionally, the mean VAS score was 4.6 (range, 0-9). Six patients could not return to work. The authors did not find any relations between initial parameters (SVA, PI, PT, LL, thoracic kyphosis from T5 to T12, VCA, and Cobb angle), and outcomes measured.

The other 5 studies evaluated different segmental measurements of spinal alignment and correlated these to functional outcomes as secondary, analyses, as it follows:

In 1994, Akbarnia et al. [21] published their work investigating 13 patients with thoracolumbar burst fractures who were managed with long rods (Harrington instrumentation) and short arthrodesis. The hardware was electively removed after 6 months. The intention of the short arthrodesis and instrumentation removal was to preserve mobility and hasten facet fusion. These patients had a mean age of 33.8 years and 76.9% were male. Patients were followed for a mean of 74 months (range, 34-118 months). Two (15.4%) cases had incomplete neurological deficits, while the rest had normal function. Cobb angles were measured preoperatively, at 9 months, and at the end of follow-up, using lateral radiographs; Kyphotic angles were positive, whereas lordotic angles received a negative value. All patients were able to walk independently without assistance and independent to others for daily activities at last follow-up. Seven patients kept working full-time in the same job as before trauma, 4 had to change job, and 2 patients were working part-time. In analyzing the individual patient's data provided, no correlation was found between preoperative (p=.079) and postoperative angles (p=.488), and pain at last follow-up. These angles were also not significantly associated with return to work, in a multinominal regression analysis (p=.375).

Although the association between initial angles and functional outcomes were not directly addressed by Mumford et al., the authors provided raw data from which comparative analysis could be done [22]. The sample under investigation consisted of 41 neurologically intact patients with single-level thoracolumbar burst fractures, with middle-column involvement (bone fragment retropulsion), treated conservatively. Patients were followed for a mean time of 24.4 months (range, 5.7-65.9 months). The work status was divided into categories: cannot work, working at a lower strenuous level than before injury, and working at the same or in better activity than before injury. The overall function outcome was categorized as poor, fair, good, and excellent, according to the compiled results of the other functional and pain scales. Our

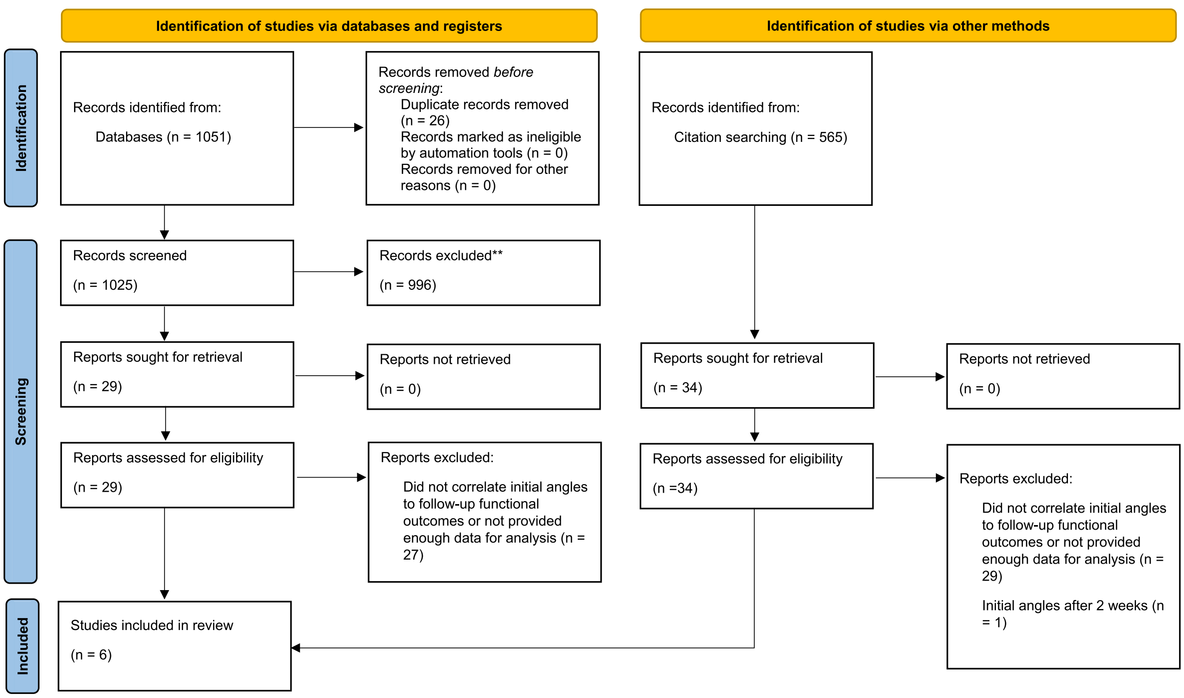

Fig. 2. PRISMA 2020 flow diagram showing the screening process for this review. *From:* Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://www.ncbi.nlm.nih.gov/pubmed/33782057 [16].

Table 2
Summarized data of papers included.

Author	Patients, n	Angles measured	Outcomes measured	Significant correlation?	Level of evidence*
Thelen et al. [25]	76	VCA, Cobb angle, Gardner angle	VAS spine score	No correlation	Level III
Joaquim et al. [20]	22	PT, PI, LL, TK, VCA	ODI, SF-36, and VAS pain.	No correlation	Level III
Defino et al. [24]	18	SI	Denis pain scale, Denis work scale, and SF-36.	No correlation	Level III
Siebenga et al. [23]	32 (17 surgical and 15 nonsurgical)	VCA, Cobb angle	RMDQ-24, VAS pain, VAS spine score and return to work.	No correlation	Level II
Akbarnia et al. [21]	13	Cobb angle	Pain and work status	No correlation (work status not evaluated).	Level III
Mumford et al. [22]	42	Cobb angle	Work status and overall outcome	No correlation	Level III

* According to the Levels of Evidence For Primary Research Question, adopted by the North American Spine Society January 2005. https://www.nassopenaccess.org/cms/10.1016/j.xnsj.2020.100037/attachment/61eb8a96-9c07-486c-9e23-214fce73e321/mmc6.pdf, access on Jun 26, 2024.
LL, lumbar lordosis; ODI, Oswestry disability index; PI, pelvic incidence; PT, pelvic tilt; RMDQ-24, Roland Morris Disability Questionnaire-24; SF-36, 36-Item Short Form Survey; SI, sagittal index; TK, thoracic kyphosis; VAS, visual analog scale; VCA, vertebral compression angle.

analyses demonstrated that initial Cobb angles did not significantly correlate with work status (p=.103) and overall outcome (p=.671). Average pain was 2.4 (range, 1-5), however, no sufficient data was provided to investigate its relationship with initial angles.

Siebenga et al. prospectively evaluated the results of patients aged 18-60 years (mean age, 45.7 years) with traumatic compression (and burst) fracture (Magerl type A) of T10-L4 vertebras, with no neurological deficit, who were randomized for either nonsurgical or surgical treatment [23]. The first group had conservative treatment (n=15), with initial bed rest followed by Jewett brace use for 3 months, and physiotherapy. The surgical group (n=17) consisted of patients who were selected to receive a short segment fixation, with use of Jewett brace postoperatively, followed by the elective removal of the hardware after a period of 9-12 months. Of note, 2 cases in the surgical group were found to have a type B fracture intraoperatively, and a decision was made to keep the hardware. During the follow-up time (mean, 4.3 years) the VAS pain (in this paper, scores varied from 0 to 100, with 0 being considered the worst pain imaginable), VAS spine (same as in VAS pain), and RMDQ-24 scores (ranges from 0 [no disability] to 24 [severe disability]) as well as return to work functional results were assessed. Initial VCA and Cobb angles did not correlate with these outcomes in both surgical (For VAS pain, VAS spine score, and RMDQ-24, respectively, the VCA p-values were: .876, .891, and .733; Cobb p-values: .979, .609, and .822) and nonsurgical groups (VCA p-values: .386, .361, and .663; Cobb p-values: .491, .552, and .858).

Another prospective study, conducted by Defino et al. [24], on 20 patients with burst fractures treated with posterior arthrodesis, fixation, and autologous transpedicular graft, evaluated pain (Denis scale for pain), return to work (Denis scale for work), and the SF-36 during follow-up evaluations. These patients had a mean age of 36.6±10.6 years (range, 19-60 years), and 16 (80%) were male. Affected vertebras were T10 (n=1), T12 (n=4), L1 (n=5), L2 (n=6), L3 (n=3), and L5 (n=1). All patients, except for 1 (who was Frankel C), were graded as Frankel E. Mean follow-up time was 2 years, and data for 18 patients was available at the end of the study. The initial SI ranged from 8° to 32° preoperatively (mean, 20.67°±6.15°), with a significant change at the immediate postoperative period and remaining stable until the end of the study.

In their study [24], multiple parameters were evaluated: the patient classified as Frankel C had an improvement to Frankel D at last follow-up, whereas all the other patients remained in Frankel E without changes. Also, 8 patients were pain-free, 4 had minimal pain not requiring anti-inflammatory drugs, 3 had moderate pain requiring anti-inflammatory drugs, and 3 had moderate-severe pain requiring work absence and significant impact on daily activities at the time of last evaluation. Workwise, 9 (50%) patients were able to return to their jobs, 4 (22%) were working full-time in a different function, 2 (11%) were working part-time with limitations, and 3 (17%) were not working. Analyses of the data provided on individual cases showed that neither preoperative nor postoperative SI correlated with the subcategories of the SF-36 questionnaire: physical function (preop p=.840; postop p=.599), role limitations due to physical health (preop p=.342; postop p=.992), role limitations due to emotional problems (preop p=.331; postop p=.853), vitality index (preop p=.146; postop p=.357), mental health index (preop p=.415; postop p=.609), social functioning index (preop p=.584; postop p=.903), pain (preop p=.224; postop p=.443), and general health perception index (preop p=.483; postop p=.428).

Thelen et al. [25] evaluated patients with thoracolumbar fractures that underwent minimally invasive surgical treatment, with a mean follow-up of 8.5±8 months. The authors investigated the correlation between immediate postoperative Cobb, Gardner, and VCA and VAS spine score. Significant angle reduction was observed after treatment, but a significant loss of correction was also found. No statistically significant relationship between VAS spine score at last follow-up and initial angles were found, although the preoperative VCA almost reached statistically significant association (p=.06).

Discussion

The identification of outcome predictors is of utmost importance for clinical decision making, managing patient expectations, and predicting the course of an illness [26,27]. In some situations, these predictors are gathered into a scoring or classification system to guide clinical practice and research [28]. In spinal trauma, factors such as mobility and sphincter control have shown to be related to functionality and independence [26,27,29,30]. So far, the role of initial spine angles has not been thoroughly assessed for such purposes. Simple plain radiographs, CT scans, and/or MRI are obtained as part of the initial assessment in most of the patients with spine trauma in the urgency setting [31]. These are used to evaluate anatomy, spinal cord compression status, and fracture morphology. The measurement of multiple spine parameters and angles can also be obtained from the same images [26,27,30,32].

Some studies in deformity/degenerative cases have shown the correlation between spine deformity, pain, and functional status. For example, Petcharaporn et al. studied the effects of kyphosis (≥45 degrees) in 50 patients with spinal deformity, comparing them to 50 patients with normal spinal curvature. They concluded that kyphosis and pain, general self-image, functionality, and level of activity were strongly correlated [13]. In 2014, Pellise et al. evaluated patients with spinal deformity, identified from the European Spine Study Group (ESSG) database, by measuring their coronal Cobb angle, sagittal curves, spinopelvic parameters, global tilt, and lordosis gap. They concluded that spinal deformity is debilitating and has clinical impact on physical function [14].

Despite the vast and evident effect of spinal misalignment negatively impacting the functional outcome for spinal deformity and degenerative conditions, this association is uncertain in trauma, where some degree of spinal malignment may be compensated for as most of these patients have good baseline health status and more efficient compensatory mechanisms. However, severe spinal misalignment from trauma may also result in irreversible neurologic injury, regardless of this baseline, as documented in cases series of post-traumatic deformities [11,33].

We initially hypothesized that some degree of deformity at the beginning of treatment could be a predictor of long-term QoL, pain, and activity/disability outcomes, especially in patients without instrumentation, in which case the deformity progression is expected to be more intense than in instrumented cases [34,35]. However, this research has shown that these associations are not supported by the current literature.

Of note, all the papers included used a cohort of patients with compression-type injuries (AO Spine type A). We speculate that all type B and type C injuries were surgically treated, and the likelihood of post-traumatic deformity/spinal misalignment is rare. A potential explanation to the lack of correlation of radiological measurements and outcome is that trauma patients are young and may have more efficient methods of "physiological" compensation of local deformities when compared with patients with other spinal disease [33]. These may explain at least in part some of our findings.

It is important to note that, except for 1 single paper [20] that primarily addressed the initial angles-functional outcomes relationship, all the studies found were not designed to answer this question. The fact that 4 (66.7%) papers were included only because they provided enough individual data, allowing us to do our own analysis, just highlights the low interest in this topic. Considering that the measurement of these parameters can be made at low cost, with easy reproducibility, and with readily availability, there is an unexplored potential that should be addressed in further research, including different treatment modalities and fracture types.

Additionally, despite the lack of correlation of spinal alignment and functional outcomes in this review, we believe that some patients with post-traumatic kyphosis may have several functional disabilities, as it is in degenerative cases. However, when looking at the related literature, in a general population, the lack of correlation in samples studied suggest that functional outcome of type A injuries may have a strong relationship with patients' individual factors instead of objective radiological measurements. Pain perception, muscle status, premorbid functional condition, and mental health may each play a major role in the functional outcomes, rather than a specific segmental radiological measurement. On the other hand, we can also speculate that a more accurate form of radiological assessment of spinal alignment in spine trauma patients is necessary [33].

Strengths and limitations

Although a thorough literature search was performed, very few low-level evidence papers fit our inclusion criteria. To extract as much information as possible, we performed analysis on individual data provided by the papers if present – but a metanalysis was not feasible due to high study heterogeneity (both in the radiological as well as in the functional assessment). This method of data evaluation can be criticized by that fact that the included studies were not designed to investigate our main question, and therefore their cohorts may not be appropriate for such analyses. Also, we did not control for confounding and other associated variables, as these were not reported in the original manuscripts. Therefore, the data here presented may not be ideally accurate, and any conclusions from this point on are not well supported. On the other hand, the lack of correlation of radiological measurements and spinal function in all included studies highlights the strength of our findings despite these limitations.

Conclusions

We did not find any correlation between the radiological outcome and functional outcomes of patients with TLSF. The lack of specific spinal trauma literature to answer this systematic review questions was evident, especially when we compared to the literature on spinal deformity and degenerative diseases. Well-designed prospective studies evaluating the role of spinal alignment and functional outcomes of TLSF are needed.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Previous presentations/publications

The contents of this work, either in whole or in parts, have not been published elsewhere.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2024.100529.

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