ORIGINAL ARTICLE
TRAUMA
http://dx.doi.org/10.1590/S1808-185120222201262409

EVALUATION OF KYPHOSIS MEASUREMENT IN THORACOLUMBAR SPINE FRACTURES

AVALIAÇÃO DA MENSURAÇÃO DA CIFOSE NAS FRATURAS DA COLUNA TORACOLOMBAR

EVALUACIÓN DE LA MEDICIÓN DE CIFOSIS EN FRACTURAS DE LA COLUMNA TORACOLUMBAR

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ABSTRACT

Objectives: Evaluate the reliability and reproducibility of the kyphosis measurement in thoracolumbar spine traumatic fractures by different assessment methods in different types of fractures. Methods: Fifteen fractures of the thoracolumbar spine, previously classified into types A, B, and C according to Magerl's classification, were evaluated. The value of kyphosis was measured using five different methods: (1) Cobb angle; (2) Gardner's method; (3) back wall method; (4) angle of adjacent endplates; and (5) wedge angle. The measurements were performed by five independent observers and repeated five times with a minimum interval of two weeks between each evaluation. Results: Intraobserver reliability was excellent among the five observers, evidencing good reproducibility of the methods. The five methods used also showed great intraobserver reliability in the global analysis, with methods one and four being more consistent. Conclusion: Although there is no universal agreement on measuring kyphosis in thoracolumbar fractures, our study concluded that method 1 (Cobb angle) and method 4 (adjacent endplate angle) presented the best interobserver reliabilities. Furthermore, the use of digitized radiographs and a simple computer program allowed the performance of highly reliable and reproducible measurements by all methods, given the high intraobserver reliability. ***Level of Evidence II; Comparative study.***

Keywords: Spinal Fractures; Kyphosis; Diagnostic Imaging.

RESUMO

Objetivos: Avaliar a confiabilidade e reprodutibilidade da mensuração da cifose nas fraturas traumáticas da coluna toracolombar por diferentes métodos de avaliação nos diferentes tipos de fraturas. Métodos: Foram avaliadas 15 fraturas na coluna toracolombar previamente classificadas em tipo A, B e C de acordo com a classificação de Magerl. Em cada caso, foi medido o valor da cifose através de cinco diferentes métodos: (1) ângulo de Cobb; (2) método de Gardner; (3) método das paredes posteriores; (4) ângulo das placas terminais adjacentes; e (5) ângulo de cunha. As mensurações foram realizadas por cinco avaliadores independentes e repetidas cinco vezes com intervalo mínimo de duas semanas entre cada avaliação. Resultados: A confiabilidade intraobservador mostrou-se excelente entre os cinco avaliadores, evidenciando boa reprodutibilidade dos métodos. Os cinco métodos utilizados também apresentaram grande confiabilidade intraobservador na análise global, sendo mais consistentes o método 1 e o método 4. Conclusão: Apesar de não haver concordância universal em como medir a cifose nas fraturas toracolombares, nosso estudo concluiu que o método 1 (ângulo de Cobb) e o método 4 (ângulo das placas terminais adjacentes) apresentaram as melhores confiabilidades interobservadores. Além disso, o uso de radiografias digitalizadas e um programa computadorizado simples permitiram a realização de medidas altamente confiáveis e reprodutíveis por todos os métodos, visto pela elevada confiabilidade intraobservador. ***Nível de evidência II; Estudo Comparativo.***

Descritores: *Fraturas da Coluna Vertebral; Cifose; Diagnóstico por Imagem.*

RESUMEN

Objetivos: Evaluar la fiabilidad y reproducibilidad de mensuración de cifosis en fracturas traumáticas de la columna toracolumbar por diferentes métodos de valoración en diferentes tipos de fracturas. Métodos: Se evaluaron quince fracturas de columna toracolumbar, previamente clasificadas en los tipos A, B y C según la clasificación de Magerl. En cada caso, el valor de la cifosis se midió utilizando cinco métodos diferentes: (1) ángulo de Cobb; (2) método de Gardner; (3) método de la pared posterior; (4) ángulo de placas de extremo adyacentes; y (5) ángulo de cuña. Las mediciones fueron realizadas por cinco evaluadores independientes y repetidas cinco veces con un intervalo mínimo de dos semanas entre cada evaluación. Resultados: La confiabilidad intraobservador fue excelente entre los cinco evaluadores, evidenciando una buena reproducibilidad de los métodos. Los cinco métodos utilizados también mostraron una gran fiabilidad intraobservador en el análisis global, siendo el método 1 y el método 4 más consistentes. Conclusión: Aunque no existe un acuerdo universal sobre

Study conducted by the Hospital das Clínicas, Faculdade de Medicina de Ribeirão Preto, Ribeirão Preto, SP, Brazil.
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Received on 03/25/2022 accepted on 10/31/2022
Reviewed by: Murilo Daher

cómo medir la cifosis en las fracturas toracolumbares, nuestro estudio concluyó que el método 1 (ángulo de Cobb) y el método 4 (ángulo de la placa terminal adyacente) presentaron las mejores confiabilidades entre observadores. Además, el uso de radiografías digitalizadas y un programa informático simple permitieron realizar mediciones altamente fiables y reproducibles por todos los métodos, dada la alta fiabilidad intraobservador. ***Nivel de evidencia II; Estudio Comparativo.***

Descriptores: *Fracturas Vertebrales; Cifosis; Diagnóstico por Imagen.*

INTRODUCTION

The indication of treatment for thoracolumbar spine fractures has been based on the type of fracture, presence of neurological injury, associated injuries, and the measurement of kyphosis of the fractured vertebra or vertebral segment.[1] Many studies consider kyphosis above 15-30 degrees as a parameter for indicating the surgical treatment, and its measurement is commonly performed using plain radiographs.[1-7] Although it is considered a simple angular value, there is no universal consensus on measuring this angle. Some radiographic parameters denote potential sources of variability in the measurements of lateral radiographs, such as the quality of the examination, the type and location of the fracture, and the radiographic center of the beam concerning the vertebral level in question.[8]

Different methods have been proposed for measuring kyphosis of the fractured vertebral segment.[2,3,8-11] In our study, the five methods included were: (1) angle between the upper endplate of the proximal intact vertebra and the lower endplate of the vertebra distal to the fractured vertebra, or 'Cobb angle'; (2) angle between the upper endplate of the proximal vertebra and the lower endplate of the fractured vertebra, or 'Gardner method'; (3) posterior wall method, *i.e.,* angle between the posterior wall of the body of the proximal intact vertebra and the posterior wall of the body of the intact vertebra distal to the fractured vertebra; (4) endplate angle, *i.e.,* the angle between the posterior wall of the body of the proximal intact vertebra and the posterior wall of the body of the intact vertebra distal to the fractured vertebra. The angle between the posterior body wall of the proximal intact vertebra and the posterior body wall of the intact vertebra distal to the fractured vertebra; (4) adjacent endplate angle, which is the angle between the lower endplate of the intact vertebra proximal to the fractured vertebra and the upper endplate of the intact vertebra distal to it, and (5) wedge angle, formed by the upper and lower endplate of the fractured vertebra. (Figure 1)

Because there is no consensus or standardization on using one method or a combination of them, their choice may vary worldwide according to the surgeon's preference or familiarity. Using different techniques to measure the same parameters can result in different results and thus lead to treatment variability for certain types of fractures.[11-13] A study by Sadiqi and colleagues[1] conducted among an international community of spine trauma specialists from all regions of the world identified that the Cobb angle was the most frequently used method in the thoracolumbar spine among 107 surgeons from 43 different countries, and the posterior wall method was the least used.

Considering the importance of the angular value of kyphosis of the fractured segment as one of the parameters classically used for therapeutic decision or evaluation of treatment results[1,3] its measurement should be reliable and reproducible. However, the performance of its measurements is associated with a certain degree of error in obtaining them. The present study evaluated the intraobserver and interobserver reliability of the methods of measuring sagittal kyphosis in the three types of thoracolumbar spine fractures. Both the overall reliability of each method and the agreement between the method and fracture type were evaluated.

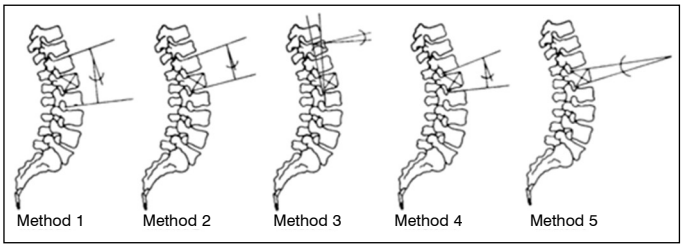

Figure 1. Methods of measuring kyphosis of the fractured vertebral segment. Method 1 - Cobb's angle; Method 2 - Gardner's method; Method 3 - posterior wall angle; Method 4 - adjacent endplates angle; Method 5 - wedge angle.

MATERIALS AND METHODS

After approval by the Research Ethics Committee of the Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo - HCFMRP-USP (opinion number 5.226.768), a cross-sectional study of kyphosis deformity measurements in thoracolumbar spine fractures was carried out. The study was exempted from obtaining informed consent due to the impossibility of contacting these patients and the prior anonymization of the patients. Profile plain radiographs were obtained from adult patients admitted to the orthopedic department of the Emergency Unit of the HCFMRP-USP with a diagnosis of traumatic vertebral fracture of the thoracolumbar spine at a single level, with the examination covering the fractured vertebra and adjacent intact vertebrae. Five radiographs were selected for each fracture type (A, B, and C), previously subdivided and classified according to Magerl's classification.[14] The level of the fractured vertebra was T12 in five patients, L1 in five, L2 in four, and L3 in one patient.

In each case, the angular value of kyphosis of the fractured segment was measured using the five most relevant methods described in the literature: (1) Cobb's angle; (2) Gardner's method; (3) posterior wall angle; (4) adjacent endplate angle; (5) wedge angle. Five independent evaluators with similar experience in spine surgery participated in the study. Each of these performed the measurements on digital radiographs using the computerized Surgimap® program, with the same tool in all cases. On each radiograph, the raters took five measurements using the five methods, with a two-week interval between each measurement, without being aware of their previous results. The data obtained were entered into a database and then used for statistical analysis.

Statistical analysis was performed by descriptive data statistics using *R Studio* software with the *Intraclass correlation coefficient (ICC)* function *for one-way and two-way models*. The parameters used were: model = *two-way,* type = *agreement, and* unit =*single.* The intraclass correlation coefficient (ICC) was calculated for agreement analysis intra- and interobserver reliability.[15-17] Intraobserver reliability assessed the reproducibility of each observer for each method used, considering the five measurements performed for the same radiograph. Interobserver reliabilities were obtained to assess the overall agreement between the five raters for each of the methods independently and for each related specifically to each fracture type. The results analyzed the best methods according to an absolute agreement. Koo and Li suggest that ICC values of less than 0.5 indicate low reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability and values greater than 0.9 indicate excellent reliability.[15] Therefore, the closer the ICC is to 1, the greater the agreement between values in the same group, while a low ICC closer to zero indicates less similarity between the values.

RESULTS

Intra-observer reliability

The intraobserver reliability was excellent for the five raters participating in the study, with ICC ranging from 0.938 to 0.989. Considering the intra-observer analysis individually per fracture, the reliability of the methods was high in the vast majority of the

evaluations (Table 1). In type A fractures, the intraclass correlation coefficient ranged from 0.982 to 0.993 for rater 1, 0.985 to 0.994 for rater 2, 0.990 to 0.996 for rater 3, 0.945 to 0.988 for rater 4, and 0.963 to 0.988 for rater 5, with excellent results in all cases. In type B fractures, the ICC ranged from 0.940 to 0.992 for evaluator 1, 0.980 to 0.991 for evaluator 2, 0.782 to 0.991 for evaluator 3, 0.491 to 0.962 for evaluator 4, and 0.806 to 0.953 for evaluator 5. In this type of fracture, we occasionally observed two results classified as poor (ICC 0.491 - rater 4's method 3) or moderate (ICC 0.580 - rater 4's method 4); all other results were rated as good or excellent. In type C fractures, the ICC ranged from 0.970 to 0.992 for evaluator 1, 0.965 to 0.993 for evaluator 2, 0.974 to 0.995 for evaluator 3, 0.881 to 0.969 for evaluator 4, and 0.948 to 0.972 for evaluator 5. Except for a single result rated as good (ICC 0.881 - evaluator four methods 3), all other results for type C fractures had an excellent intra-observer agreement among the different methods.

Table 1. The intraclass correlation coefficient for intra-observer reliability uses different methods for each fracture type.

Fracture	Observer	Method 1	Method 2	Method 3	Method 4	Method 5
A	1	0,991	0,989	0,991	0,993	0,982
	2	0,986	0,991	0,992	0,994	0,985
	3	0,994	0,992	0,99	0,996	0,992
	4	0,988	0,963	0,945	0,96	0,979
	5	0,985	0,988	0,987	0,986	0,963
B	1	0,976	0,99	0,94	0,975	0,992
	2	0,98	0,99	0,99	0,985	0,991
	3	0,991	0,977	0,782	0,976	0,919
	4	0,94	0,962	0,491	0,58	0,809
	5	0,937	0,948	0,806	0,886	0,953
C	1	0,988	0,974	0,992	0,989	0,97
	2	0,993	0,985	0,965	0,991	0,992
	3	0,995	0,986	0,986	0,993	0,974
	4	0,935	0,964	0,881	0,969	0,934
	5	0,96	0,96	0,971	0,972	0,948

Interobserver reliability

Using intraclass correlation coefficients for each measurement method, all showed high interobserver reliability. Method 1 (Cobb angle) and method 4 (angle of adjacent endplates) showed the most consistent correlation coefficients, with excellent and identical ICC of 0.918. Method 2 (Gardner's method) had the third-best result with an ICC of 0.905, followed by method 3 (posterior wall angle) with an ICC of 0.808. The method with the lowest inter-rater agreement was 5 (wedge angle), with an ICC of 0.794, although this is still considered a good result.

Regarding the fracture types alone, all of them showed excellent interobserver agreement in their measurements. Type A fractures provided the highest agreement, with an ICC of 0.921, followed by type C with an ICC of 0.918, and finally, type B with an ICC of 0.819. When comparing each measurement method to the specific fracture types, we concluded that the methods that showed the highest and lowest reliability for type A fractures were, respectively, methods 4 (angle of adjacent endplates), with an ICC of 0.959 and 5 (wedge angle), with an ICC of 0.742. For type B fractures, the most reliable method was 2 (Gardner's method) with an ICC of 0.883, and the least reliable was 3 (posterior wall angle) with an ICC of 0.326. In type C fractures, method 4 (angle of adjacent endplates) was the most reliable (ICC of 0.924), and method 3 (angle of posterior walls) was the least reliable (ICC of 0.849). Figure 2 illustrates all measurements (in degrees) taken by the five raters using the five measurement methods, with the fractures subdivided into types A, B, and C.

DISCUSSION

Radiographic evaluation of the fractured vertebral segment has been one of the parameters used for the indication of therapy and follow-up of patients with thoracolumbar spine fractures, highlighting the measurement of the height of the vertebral body and kyphosis of the fractured vertebral segment.[1] Although there is no consensus as to which exam is most appropriate for assessing the degree of kyphosis in these traumatic injuries, plain radiography has proven to be the most reliable tool (intra and interobserver agreement)

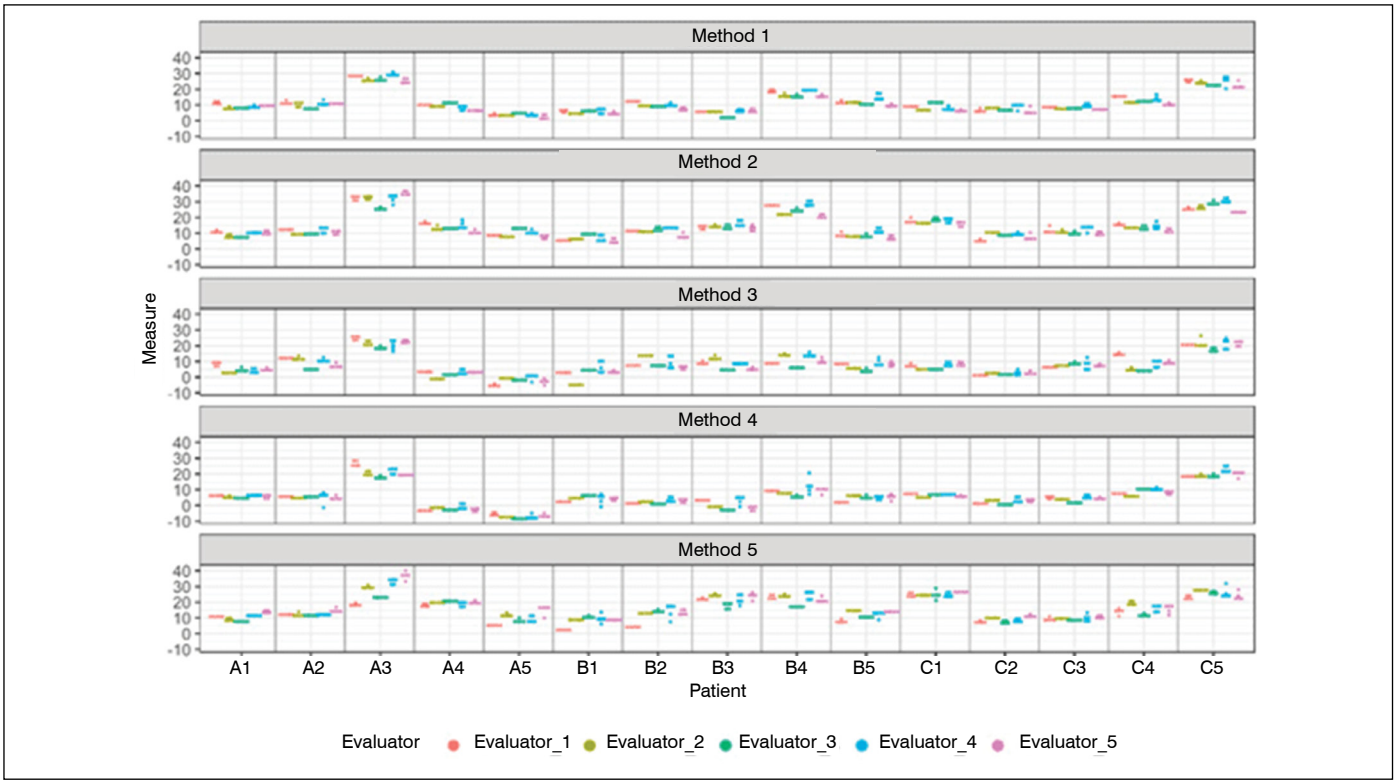

Figure 2. Each rater's kyphosis measurements (in degrees) using the five measurement methods in each of the 15 fractures. A1, A2, A3, A4 and A5 = type A fractures. B1, B2, B3, B4 and B5 = type B fractures. C1, C2, C3, C4 and C5 = type C fractures.

when compared to exams such as computed tomography and magnetic resonance imaging.[2] Kyphosis above 15-30 degrees has been associated with instability[4-7] and there is growing agreement that kyphotic deformity may be associated with back pain.[18-20] The use of a reliable and reproducible kyphosis assessment technique is imperative in scientific communications and follow-up of kyphosis of the fractured segment.

Manual measurement of the kyphosis angle has been the traditional technique for many years. With the advent of technology, digital programs have provided better visualization and measurement of kyphosis. These devices have increased in everyday hospital environments, contributing to greater practicality and agility. It was demonstrated that the five methods of kyphosis measurement used in our study, when performed digitally and compared to the manual technique, showed high reliability and reproducibility.[21] In our study, we used the computerized Surgimap® program, using the angular measurement tool in all cases and storing the measurements performed. More recently, studies have demonstrated the use of smartphone applications to measure various spinal parameters, including thoracolumbar kyphosis, with good accuracy and reliability.[22]

One of the most popular methods for measuring kyphosis is the 'Cobb angle'. It was originally designed on anteroposterior radiographs to assess scoliosis,[23] and this method is the most widely used for quantification of this deformity.[24] The same can be said for kyphosis measurement since the Cobb angle on lateral radiographs is the most useful method.[25] In our analysis, the Cobb angle (method 1), together with the angle of adjacent endplates (method 4), showed the highest inter-rater reliability (both with an ICC of 0.918). A similar study by Kuklo and colleagues[8] found that the Cobb method also had the best intra- and interobserver reliability in an analysis using the same five methods of kyphosis measurement that we studied. At the same time, they also noted that methods 1 and 4 were found to be the most reliable and to vary the least overall, which corroborates our results. In the intercontinental work by Sadiqi and colleagues,[1] the most suitable technique for measuring fracture kyphosis was the Cobb angle measurement (method 1), followed by the wedge angle (method 5). Despite having the lowest reliability among the methods analyzed in our study, methods 3 and 5 still showed good agreement, with interobserver ICC of 0.808 and 0.794, respectively.

Alvarenga and collaborators[26] analyzed the impact of surgeons' experience in evaluating kyphosis by different methods. Participants included orthopedic residents with up to three years of experience, fellows specializing in spine surgery with up to five years of experience, and spine surgeons with at least ten years of experience; the latter group showed the most uniform results. They noted that methods 1 and 4 were more reproducible among most of the participating surgeons, agreeing with our findings.

We believe that the higher interobserver reliability obtained using methods 1 and 4 is due to the use of intact endplates as reference lines for the measurement of the kyphosis angle, decreasing the differences between measurements. Fractured vertebrae presenting vertebral body sinking or endplate comminution may represent consensual limitations for defining the reference line for angular measurement. For this reason, some researchers have suggested using the endplates adjacent to the fractured vertebra to measure kyphosis.[8] However, because this method may be affected by the deformity of the adjacent discs due to the fracture, other researchers have proposed using the anterior and posterior heights and the width of the affected vertebral body to estimate the kyphotic angle.[27]

The integrity of the vertebra used as a reference in a given method does not exclude the possibility of measurement variations. Although it can be considered a flat surface for angular measurement, the architecture of the upper endplate usually has a raised ridge on its posterior aspect that will alter the angular value whether or not it is adopted as a reference. Because there is no standard for determining this plane, it was proposed to use the line parallel to the flat body surface in these cases and to disregard the posterior crest of the superior endplate.[28] Other potential sources of divergence for determining radiographic parameters included the examination quality, the fracture's location, and the beam's radiographic center relative to the vertebral level.[8]

Interestingly, when we analyze the methods individually for the different fracture types classified by Magerl, the interobserver reliability of each method varies. Method 4 was the most reliable for type A and C fractures, but method 2 was the most reliable for type B fractures. Magerl's classification of thoracolumbar fractures was developed using as a parameter the progressive morphological damage determined by three fundamental forces: compression (type A fractures), distraction (type B fractures), and axial rotation (type C fractures).[14] By themselves, the different morphological damage represented by the three categories of fractures constitutes a potential source of divergence for the determination of reference lines for the measurement of angles, which may justify the different reliability among the methods for each specific type of fracture.

An important limitation of our study is that the reference parameters in the measurements of the angles were not objective because there was also a portion of personal judgment. There was also a portion of personal judgment. Therefore, human error may be present in obtaining the values. On the other hand, the fact that evaluators performed the measurements with similar experiences in spine surgery contributed to the high reproducibility of the results.

CONCLUSION

The measurement of kyphosis deformity in thoracolumbar spine fractures has been given as a simple angle. However, there is no universal agreement on how to measure this angle. Our study concluded that the Cobb method and the method of endplates opposite the fractured vertebra showed the best interobserver reliability. In addition, the use of digitized radiographs and a simple computer program allowed highly reliable and reproducible measurements to be made by all methods, thus suggesting the use of these methods for digital measurements in the routine clinical practice of a spine surgeon.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS: Each author contributed individually and significantly to the development of this article. VRC: substantial contribution in the conception of the work, writing of the work and critical review of its intellectual content, final approval of the manuscript version to be published; LRN: substantial contribution in the conception of the work, final approval of the manuscript version to be published; VNT: substantial contribution in the conception of the work, final approval of the manuscript version to be published; PFDRRE: substantial contribution in the conception of the work, final approval of the version of the manuscript to be published; RCO: substantial contribution in the conception of the work, final approval of the version of the manuscript to be published; HRTC: substantial contribution in the conception of the work, final approval of the version of the manuscript to be published; HLAD: substantial contribution in the conception of the work, writing of the work and critical review of its intellectual content, final approval of the version of the manuscript to be published.

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