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MANAGEMENT OF RETAINED GUNSHOT INJURIES TO THE SPINE: A SYSTEMATIC LITERATURE REVIEW

MANEJO DE LESÕES POR ARMA DE FOGO RETIDAS NA COLUNA VERTEBRAL: UMA REVISÃO SISTEMÁTICA DA LITERATURA

MANEJO DE LESIONES POR DISPAROS RETENIDAS EN LA COLUMNA VERTEBRAL: UNA REVISIÓN SISTEMÁTICA DE LA LITERATURA

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ABSTRACT

Spinal cord injuries from gunshot wounds are a major concern, ranking as the third leading cause of spinal trauma. Despite its high prevalence in some countries, there is no consensus regarding the surgical treatment of such injuries. This study aims to provide a comprehensive review of the management of retained spinal gunshot projectiles. Systematic literature review from 1999 to 2024, following MOOSE, PRISMA, and STROBE guidelines. The research question focused on the indication for the removal of retained projectiles on the spine. We have assessed treatment strategies based on spinal segment, vertebral segment, projectile type, and risk of lead poisoning. Of 331 studies, 30 were included, identifying key variables affecting therapeutic decisions. Management depends on the projectile location and neurological status. Early removal of cervical injuries is advised. Thoracic projectiles may be retained in non-progressive injuries. In the lumbar region, removal is recommended due to the potential for multiple neuronal compressions. Vertebral body projectiles only require removal if they compromise mechanical stability. Projectiles in the intervertebral disc and facet need close monitoring for lead poisoning risks, while those in paravertebral muscles usually remain unless symptoms arise. Copper and fragmented projectiles have a higher complication risk and should also be closely monitored. There is scientific evidence supporting systematized decision-making for managing retained gunshot projectiles. ***Level of Evidence II; Systematic Review.***

Keywords: Wounds, Gunshot; Injury; Evidence-Based Practice; Spinal Cord; Spinal Cord Injuries; Wounds.

RESUMO

As lesões da medula espinhal por ferimentos com arma de fogo são uma grande preocupação, classificando-se como a terceira principal causa de trauma espinhal. Apesar de sua alta prevalência em alguns países, não há consenso quanto ao tratamento cirúrgico dessas lesões. Este estudo tem como objetivo fornecer uma revisão abrangente para o manejo de projéteis retidos na coluna espinhal. Revisão sistemática da literatura de 1999 a 2024, seguindo as diretrizes MOOSE, PRISMA e STROBE. A questão de pesquisa concentrou-se na indicação de remoção de projéteis retidos na coluna vertebral. Avaliou-se as estratégias de tratamento com base no segmento espinhal, segmento vertebral, tipo de projétil e risco de intoxicação por chumbo. Dos 331 estudos, 30 foram incluídos, identificando as principais variáveis que afetam as decisões terapêuticas. O tratamento depende da localização do projétil e do estado neurológico. Recomenda-se a remoção precoce de lesões cervicais. Projéteis torácicos podem ser retidos em lesões não progressivas. Na região lombar, a remoção é recomendada devido ao potencial de múltiplas compressões neuronais. Os projéteis do corpo vertebral só requerem remoção se comprometerem a estabilidade mecânica. Os projéteis no disco intervertebral e na faceta precisam de monitoramento rigoroso quanto aos riscos de envenenamento por chumbo, enquanto os dos músculos paravertebrais geralmente permanecem, a menos que surjam sintomas. Projéteis de cobre e fragmentados têm maior risco de complicações e devem ser monitorados de perto. Existem evidências científicas que apoiam a tomada de decisões sistematizadas para o manejo de projéteis de arma de fogo retidos. ***Nível de Evidência II; Revisão Sistemática.***

Descritores: *Ferimentos por Arma de Fogo; Lesão; Prática Clínica Baseada em Evidências; Medula espinal; Traumatismos da Medula Espinal; Feridas.*

RESUMEN

Las lesiones de la médula espinal por heridas de bala son una preocupación importante, y se ubican como la tercera causa principal de traumatismo espinal. A pesar de su alta prevalencia en algunos países, no existe consenso sobre el tratamiento quirúrgico de estas lesiones. Este estudio tiene como objetivo proporcionar una revisión integral para el manejo de proyectiles retenidos en la columna vertebral. Revisión sistemática de la literatura desde 1999 hasta 2024, siguiendo las directrices MOOSE, PRISMA y STROBE. La pregunta de investigación se

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centró en la indicación de la eliminación de los proyectiles retenidos en el lomo. Hemos evaluado las estrategias de tratamiento en función del segmento espinal, el segmento vertebral, el tipo de proyectil y el riesgo de envenenamiento por plomo. De los 331 estudios, se incluyeron 30, en los que se identificaron las variables clave que afectaban a las decisiones terapéuticas. El tratamiento depende de la localización del proyectil y del estado neurológico. Se aconseja la extirpación temprana de las lesiones cervicales. Los proyectiles torácicos pueden ser retenidos en lesiones no progresivas. En la región lumbar, se recomienda la extirpación debido a la posibilidad de múltiples compresiones neuronales. Los proyectiles del cuerpo vertebral solo requieren ser removidos si comprometen la estabilidad mecánica. Los proyectiles en el disco intervertebral y la faceta necesitan un seguimiento estrecho para detectar riesgos de envenenamiento por plomo, mientras que los de los músculos paravertebrales suelen permanecer a menos que surjan síntomas. El cobre y los proyectiles fragmentados tienen un mayor riesgo de complicación y también deben ser monitoreados de cerca. Existe evidencia científica que respalda la toma de decisiones sistematizada para el manejo de los proyectiles de arma de fuego retenidos. ***Nivel de Evidencia II; Revisión Sistemática.***

Descriptores: *Heridas por Arma de Fuego; Herida; Práctica Clínica Basada en la Evidencia; Médula espinal; Traumatismos de la Médula Espinal; Heridas.*

INTRODUCTION

Spinal cord injuries caused by gunshot wounds have become a growing concern, contributing to the increasing incidence worldwide. Currently, these injuries represent the third most common cause of spinal trauma, accounting for approximately 17% to 21% of these wounds, following falls from height and traffic accidents.[1–3] Although the incidence of firearm-related crimes has decreased in some countries, this trend does not hold true in developing regions, such as parts of Latin America and Asia, where the situation has worsened.[1,4,5] These injuries increased significantly between 2007 (7%) and 2015 (15%), standing out as a significant cause of morbidity and mortality in the civilian population.[6] Men are the most affected, with the prevalence in this population ranging from 78 - 94%, with the highest incidence in the third decade of life.[7]

Among the affected spinal regions, the thoracic is the most affected segment (≈51%), followed by the cervical (≈27%) and, less commonly, the lumbar (≈21%).[8–12]

Compared to other causes of spinal trauma, gunshot wounds are associated with significantly limited functional recovery and unfavorable outcomes, such as prolonged hospitalizations and a higher incidence of secondary complications.[4,13] Neurological deficits have been observed in a wide range of 33% to 92.4% of cases, often resulting in complete spinal cord injuries.[3] Among the most common complications are cerebrospinal fluid (CSF) fistula, recurrent urinary tract infections, pressure ulcers, pneumonia, deep vein thrombosis, sepsis, wound infections, and meningitis.[14,15]

These injuries not only result in considerable physical impact but also impose a significant socioeconomic burden on the healthcare infrastructure, especially in developing countries like Brazil.[3,4,10,16,17]

Surgical treatment of gunshot wounds to the spine remains a controversial topic.[18,19] Several issues are under debate: the efficacy of decompressive laminectomy in neurological recovery, and the role of bullet removal in reducing infections are some controversies in the literature.[10,17,20]

Given the complexity involved in choosing the most appropriate surgical treatment for gunshot wounds to the spine, it is essential to develop clear guidelines that consider critical factors such as bullet position, degree of neurological injury, bullet type, and its clinical repercussions, always with the goal of achieving the best possible prognosis for patients.

The objective of this study is to synthesize literature in order to derive recommendations for the therapeutic management of spinal gunshot wounds through a systematic review.

METHODOLOGY

This systematic literature review was conducted using the following guidelines: Meta-analysis of Observational Studies in Epidemiology: A Proposal for Reporting (MOOSE), Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement, and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).

Search Strategy

We systematically searched MEDLINE/PubMed and Google Scholar databases for articles published in English, Spanish, and Portuguese from January 1999 to November 2023. The initial research question to be answered was: "Should a gunshot projectile located in the spine be removed?" Our Query box was:

Google Scholar: allintitle: wound OR Gunshot OR Spine+Gunshot OR injury+Spinal OR wound+Gunshot OR removal+spine OR bullet -rat -veterinary -horse -dogs (128 articles) MEDLINE/PubMed: Search: ((((Spine gunshot wounds) AND (Gunshot spine)) AND (Gunshot spinal injury)) AND (Spinal gunshot wound)) AND (Gunshot wound) Filters: Humans, from 1999 - 2023 (203 articles)

Selection Criteria

We selected all studies published in English, Spanish, or Portuguese between 1999 and 2023, with the search criteria described. At this stage of the research, we obtained a total of 331 articles.

Once duplicate articles were eliminated, the quality of the studies was analyzed independently by two authors and then in a group discussion to achieve consensus. The authors independently reviewed the titles and abstracts, excluding: case reports, conference abstracts, articles not directly related to gunshot wounds involving the spine, medico-legal articles, forensic medicine articles, combat (war) reports, social services/public health policies, veterinary studies (performed on dogs, horses, rats or others), radiology studies without clinical data and repeated or overlapping publications.

Doubts and disagreements about selection were discussed with the senior author. After the analysis of titles and abstracts.

RESULTS

As a result, 50 articles were reviewed through full-text analysis, of which 20 were eliminated, since they did not provide sufficient information about the study question. (Figure 1)

Ten variables that should be considered in decision-making and can influence the therapeutic options were identified: Segment of the spine (cervical, thoracic, lumbar); Location (facet, vertebral body, disc, spinal canal, paravertebral musculature), type of projectile (lead, copper, encapsulated).

The selected articles were read critically and evaluated using a checklist of these 10 variables. Each article and variable was independently scored by two spine surgeons, with any disagreements resolved by the senior researcher. A complete list of the selected studies is provided as a supplementary file.

If the article mentioned the variable but did not make a treatment suggestion, it was classified as inconclusive. Table 1 summarizes the number of studies associated with each variable.

Variable 1: Should a projectile in the cervical spinal canal be removed?

The literature reviewed supports projectile removal. For injuries with progressive neurological deficit, emergency surgery is

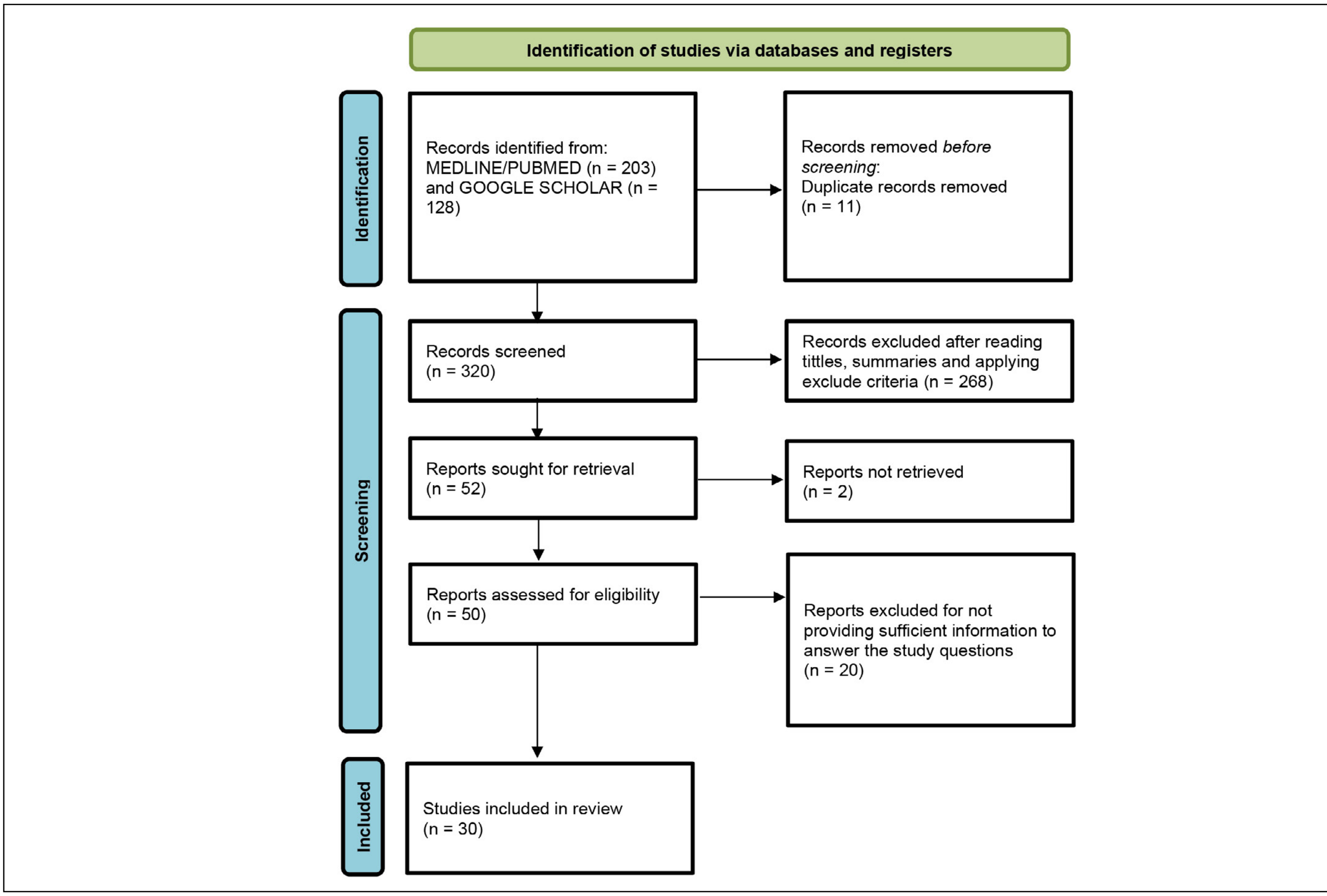

Figure 1. PRISMA flowchart of study selection.

Table 1. Variables related to the research question and a number of studies associated with the question.

Variable	Studies answering the question
Should a projectile in the cervical spinal canal be removed?	16
Should a projectile in the thoracic spinal canal be removed?	14
Should a projectile in the lumbar spinal canal be removed?	17
Should a projectile in the vertebral body be removed?	4
Should a projectile in the intervertebral disc be removed?	5
Should a projectile in the intervertebral facet be removed?	4
Should a projectile in the paravertebral muscles be removed?	3
Do you recommend monitoring lead levels?	4
Did any type of projectile influence your decision?	1
Does the number of projectile lodge in the body influence your decision?	0

absolutely indicated and should be performed as soon as possible.[18,20–22] In the case of complete or incomplete non-progressive injuries, it is recommended to remove the projectile between the 2nd and 5th day after the incident.[15,23,24] Although the studies are divergent and inconsistent in proving a difference in neurological recovery between surgical and conservative treatment. The best evidence on neurological recovery indicates up to 2 levels of improvement,[8,9,25,26] which justifies the increased risk of infection and cerebrospinal fluid leak in surgical approaches.[27] Table 2 summarizes the possible treatment strategies for a projectile within the spinal canal.

Variable 2: Should a projectile in the thoracic spinal canal be removed?

The literature review supports the maintenance of firearm projectiles in the thoracic spine, both in complete and incomplete nonprogressive injuries.[24] For injuries with progressive neurological

Table 2. Indications for removal of a gunshot wound projectile within the spinal canal. The number indicates the amount of studies recommending each strategy.

Variable/Answers	Always remove	Does not remove	Removes if there is an incomplete spinal cord injury	Removes if there is a complete spinal cord injury	Removes if there is a progressive deficit	CSF fistula	Symptomatic projectile migration	Does not conclude
Should a projectile in the cervical spinal canal be removed?	4	0	9	3	12	9	7	0
Should a projectile in the thoracic spinal canal be removed?	3	0	5	1	11	7	6	1
Should a projectile in the lumbar spinal canal be removed?	10	0	4	1	7	3	3	2

deficit, emergency surgery is absolutely indicated and should be performed as soon as possible.[18,20–22] Current studies are divergent and inconsistent in proving a difference in neurological recovery between surgical and conservative treatment. The best evidence indicates 1-2 neurological levels of recovery,[8,9,25–27] which results in minimum clinical benefits on this segment. (Table 2)

Variable 3: Should a projectile in the lumbar spinal canal be removed?

In injuries to the conus medullaris and cauda equina, there is benefit from projectile removal regardless of the patient's neurological status.[17] Due to the anatomical characteristics, a projectile in the cauda equina can compress multiple neuronal structures simultaneously, and the axonal regeneration potential of the decompressed roots is good, giving this individual characteristic of more aggressive treatment for this level of the spine (Table 2).[26] The recommended surgical time is 2 to 5 days after nonprogressive injury.[24]

Variable 4: Should a projectile in the vertebral body be removed?

Projectiles lodged in the vertebral body generally do not promote mechanical instability or significant systemic repercussions.[25,28–31] The articles reinforce the concepts of always evaluating the mechanical stability of the lesion and removing the projectiles that are in the path of a possible surgical approach.[24] Table 3 summarizes the possible treatment strategies for a projectile within the vertebral body.

Variable 5: Should a projectile in the intervertebral disc be removed?

When projectiles cause disc herniation, treatment should follow the guidelines for acute hernias, with removal indicated when there is a neurological deficit.[18] The migration of the projectile lodged in the disc has already been reported in the literature, and the appearance of neurological deficit during patient follow-up should lead to the assessment of compression by the projectile.[32] Disc projectiles present a risk of lead poisoning and must be monitored until the bullet is encapsulated and serum levels stabilize (Table 3).[33–35]

Variable 6: Should a projectile in the intervertebral facet be removed?

Synovial fluid acts as a solvent for projectiles.[36,37] Despite the rare incidence, due to the risk of lead poisoning, they must be carefully monitored until the bullet is encapsulated and serum levels are stabilized (Table 3).[33–35,38]

Variable 7: Should projectiles in the paravertebral muscles be removed?

Projectiles lodged in the muscles generally do not cause significant repercussions.[39]

Table 3. Indications for the removal of a gunshot projectile in different regions of the spine, and also for monitoring lead levels. The number indicates the number of studies recommending each strategy.

Variable/Answers	Always	Sometimes	No	Does not conclude
Should a projectile in the vertebral body be removed?	0	4	0	2
Should a projectile in the intervertebral disc be removed?	0	4	0	1
Should a projectile in the intervertebral facet be removed?	0	4	0	2
Should projectiles in the paravertebral muscles be removed?	0	1	2	0
Do you recommend monitoring lead levels?	3	0	1	6

However, it is important to be aware that the migration of the projectile lodged in the muscles has already been reported in the literature.[40] The appearance of neurological symptoms during patient monitoring must be carefully evaluated, as it can indicate projectile movement. Projectiles in the muscles are generally well tolerated (Table 3).[41]

Variable 8: Do you recommend monitoring lead levels?

Projectiles in the facet joint and disc must be monitored.[42] We recommend determining the lead level at the initial time of treatment, two weeks later, and monthly for 3 months.[42] Acceptable lead levels for adults are $<40\ \mu g/dl$ and $<10\ \mu g/dl$ in children.[38] Due to the low corrosive properties of cerebrospinal fluid (CSF), it is unlikely that a projectile lodged within the spinal canal will cause poisoning, and this should not be considered a justification for its removal (Table 3).[33]

Variable 9: Did any type of projectile influence your decision?

Copper jackets often require removal due to the high local inflammatory response they can trigger.[18,23,43] In contrast, lead bullets generally result in a less inflammatory response.[44] Therefore, careful monitoring is crucial to detect and treat any development of myelopathy. Fragmented projectiles are more likely to be absorbed, which requires more careful monitoring.[18] Only one article in our review answers variable 9.

Variable 10: Does the number of projectiles lodged in the body influence your decision?

None of the articles evaluated in this systematic review concludes on the subject.

DISCUSSION

This revision provides the current scientific evidence on decision-making for retained gunshot projectiles in the spine. For cervical spine injuries, early removal of projectiles is advised, emergently in progressive cases, to potentially enhance neurological recovery. Thoracic spine projectiles may be safely retained in non-progressive injuries, but should be removed in cases with progressive deficits. In the lumbar region, removal is recommended for both progressive and non-progressive injuries due to the potential for multiple neuronal compressions. Projectiles in vertebral bodies generally do not require removal unless they affect mechanical stability. Projectiles in intervertebral discs and facets warrant careful monitoring due to the risk of lead poisoning; in these cases, the lead level should be determined at the initial time of treatment, two weeks later, and monthly for three months.[42] Acceptable lead levels for adults are $<40\ \mu g/dl$ and $<10\ \mu g/dl$ in children.[38] Those in paravertebral muscles usually do not necessitate removal unless symptoms arise. Bullets with a copper jacket and fragmented projectiles carry a higher risk of complications and should be closely monitored.

Some concepts are general and applicable to all segments of the spine. Regardless of the previous path of the bullet, Projectile maintenance is not associated with increased risk of infection.[45,46] Due to the low corrosive nature of cerebrospinal fluid (CSF), it is unlikely that a projectile lodged within the spinal canal will cause poisoning, and this should not be considered a justification for its removal.[47]

Furthermore, broad-spectrum antibiotic prophylaxis is recommended for 48-72 hours if there is no injury to the abdominal viscera.[17,27,48,49] In the presence of abdominal viscus injury, the prophylaxis time should be extended by 10-14 days.[19] Tetanus prophylaxis should still be carried out in the emergency room if the patient does not have up-to-date immunization.[50] Removing the projectile does not cause pain relief and this complaint should be managed conservatively.[20,26,28,51] Bullet removal is associated with deafferentation pain that can be more difficult to treat.[52]

Independent of the spine segment, in cases of suspected CSF in the wound, placing a lumbar drain and monitoring the wound is recommended for early diagnosis of a fistula.[15] For patients with

CSF fistula, the surgical approach with laminectomy and primary repair of the lesion is the preferred option; in cases where repair is not possible, fibrin glue and/or synthetic or local graft can be used. This measure aims to prevent meningitis and herniation of neural contents.[45,53] When there is any indication for surgical treatment and the projectile is in the path of the access route, it should be removed so that the procedure can be performed. Projectile migration is rare but possible and may result in neurological deficits.[54] In these situations, the symptoms should be monitored, and the onset of new symptoms indicates surgical treatment to remove the projectile.[42] For injuries with progressive neurological deficit and image compatible with the deficit, emergency surgery is indicated.[18,20–22,42]

We propose, as a result of this systematic review, the following treatment algorithms. (Figure 2)

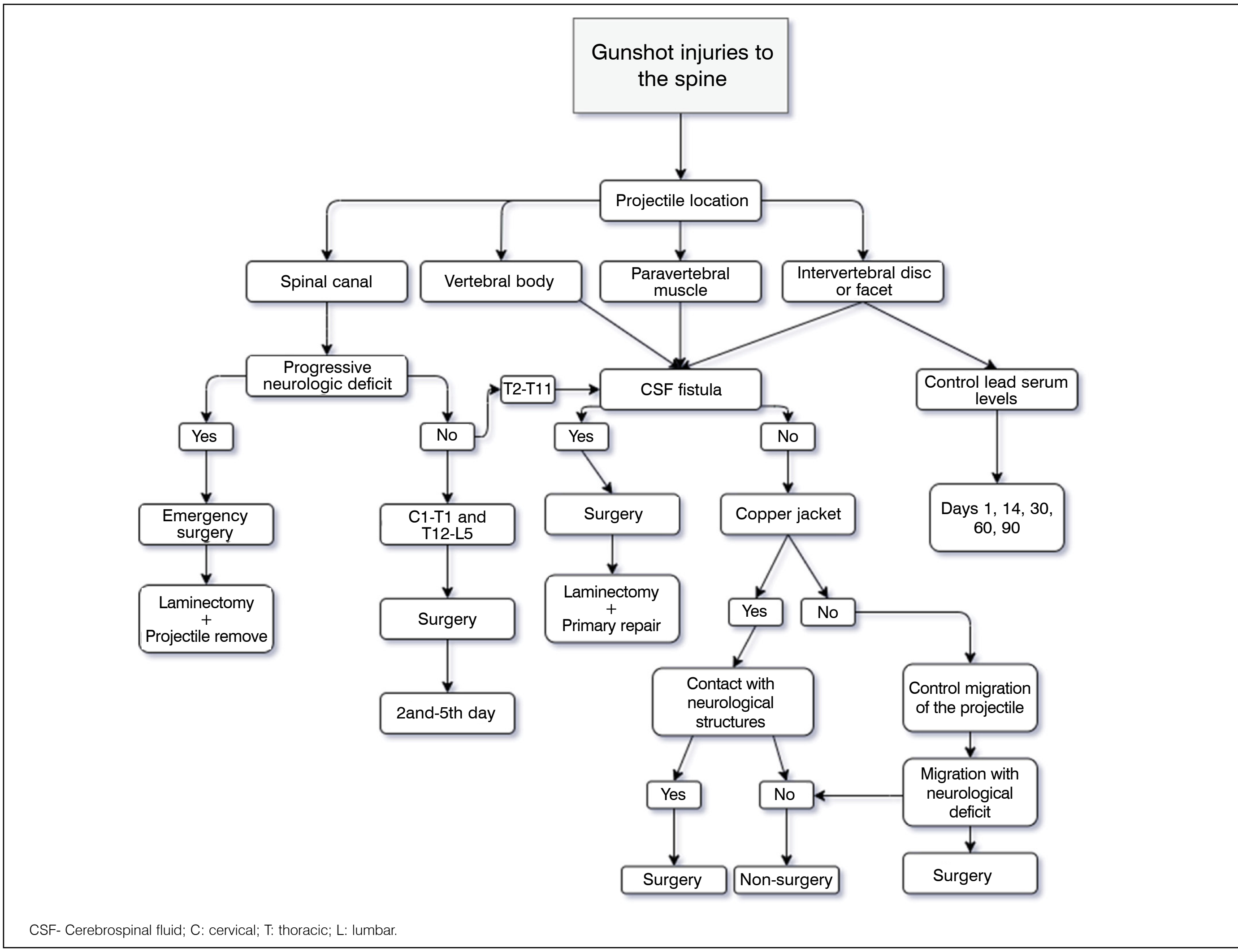

Figure 2. Treatment algorithm for retained gunshot injuries to the spine.

CONCLUSION

This systematic review provides a solid scientific foundation for decision-making in the management of retained spinal gunshot projectiles. By systematizing management and promoting evidence-based protocols, this review aims to enhance patient outcomes and safety, contributing to the standardization of clinical approaches in the treatment of spinal gunshot injuries.

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