

Precision, Safety, and Penetration: Mechanical and Functional Analogies Between the Archery Arrow and the Spinal Needle in Subarachnoid Access

Luiz Eduardo Imbelloni^{1*}, José Roberto de Rezende Costa², Richa Chandra³, Anna Lúcia Calaça Rivoli⁴, Sylvio Valença de Lemos Neto⁵, Grace Haber⁶, Sara Pereira Lima Soares de Sá⁷ and Antonio Fernando Carneiro⁸

¹Researcher Consultant at INCA, Anesthesiology Consultant at Somosalle Group, São Paulo, SP, Brazil

²Anesthesiologist and Medical Examiner, Belo Horizonte, MG, Brazil

³Professor, Department of Anesthesiology, Rohaikhand medical College and Hospital, Bareilly, India

⁴Anesthesiologist at the National Cancer Institute (INCA), Rio de Janeiro, RJ, Brazil

⁵Head of the Anesthesiology Service of the National Cancer Institute (INCA), Rio de Janeiro, RJ, Brazil

⁶Anesthesiologist at the National Cancer Institute (INCA), Rio de Janeiro, RJ, Brazil

⁷Anesthesiologist at the National Cancer Institute (INCA), Rio de Janeiro, RJ, Brazil

⁸Professor of Anesthesiology at the UFG Faculty of Medicine, Goiânia, GO, Brazil

***Corresponding author:** Luiz Eduardo Imbelloni, Researcher Consultant at INCA, Anesthesiology Consultant at Somosalle Group, São Paulo, SP, Brazil

ARTICLE INFO

Received: 📅 May 25, 2026

Published: 📅 June 03, 2026

Citation: Luiz Eduardo Imbelloni, José Roberto de Rezende Costa, Richa Chandra, Anna Lúcia Calaça Rivoli, Sylvio Valença de Lemos Neto, Grace Haber, Sara Pereira Lima Soares de Sá and Antonio Fernando Carneiro. Precision, Safety, and Penetration: Mechanical and Functional Analogies Between the Archery Arrow and the Spinal Needle in Subarachnoid Access. Biomed J Sci & Tech Res 65(5)-2026. BJSTR. MS.ID.010253.

ABSTRACT

Although both the spinal needle and the archery arrow are designed for precision-guided penetration, they are applied in profoundly different biological contexts. In spinal anesthesia, the needle must accurately traverse anatomical tissues and perforate the dura mater at a precise point to access the subarachnoid space, a highly protected compartment of the central nervous system, whereas the archery arrow is directed toward a defined external target. This article proposes a mechanical, structural, and functional analogy between the spinal needle and the archery arrow, highlighting similarities related to stability, precision, penetration, material resistance, and safety principles. A comparative table summarizes the main characteristics shared by these two instruments, and illustrative figures demonstrate their conceptual and structural similarities. In medical practice, particularly in procedures perceived as routine, such as spinal anesthesia, procedural familiarity may progressively reduce risk perception and contribute to the underestimation of latent hazards and technical vulnerabilities. In contrast, modern archery competitions operate under strict safety protocols, equipment standardization, inspection routines, and continuous technical training aimed at minimizing preventable accidents and equipment-related failures. Similarly, neuraxial anesthesia requires rigorous adherence to established safety protocols, appropriate technical expertise, anatomical precision, quality control of materials, and the exclusive use of approved intrathecal agents. Given the biological complexity and vulnerability of the neuraxis, even minor technical failures may result in severe neurological complications. The analogy between the archery arrow and the spinal needle reinforces the importance of maintaining a permanent culture of vigilance, precision, and patient safety in all procedures involving access to the subarachnoid space.

Keywords: Spinal Needle; Spinal Anesthesia; Subarachnoid Space; Neuraxis; Archery; Arrow; Competition; Patient Safety

Introduction

Ignaz Philipp Semmelweis in 1846, known as a pioneer of anti-septic procedures, required students to wash their hands with calcium hypochlorite, and correlated autopsies with puerperal fever in obstetric patients, publishing a book entitled *Etiology, Concept and Prophylaxis of Puerperal Fever* [1]. The first surgical glove was used by Caroline Hampton, head nurse to William Stewart Halsted, who pioneered the use of rubber gloves during surgery [2]. Halsted developed these gloves to protect Hampton's hands, who suffered from dermatitis due to chemicals used during operations. The invention of surgical gloves was a loving gesture that became a universal medical practice, significantly reducing surgical infections. Thomas Jonnesco published an approach to the three subarachnoid spaces in the thoracic region, providing conditions for surgery involving the skull, head, neck, and thorax; however, in the photographs demonstrating the access, the author was not wearing gloves [3]. Probably, at that time, access to the subarachnoid space was performed without the scientific rigor currently required. The ideal spinal anesthesia needle should facilitate identification of the subarachnoid space and injection of the local anesthetic, while minimize deformation and reduce the incidence of headaches. Cutting-tip needles, with a stylet that fits perfectly into the bevel and a medium-sized angled tip, allow cerebrospinal fluid (CSF) to appear immediately after entering the subarachnoid space, confirming correct needle placement. Pencil-point needles (Whitacre and Sprotte) cannot be compared to archery arrows; only cutting-point needles share such similarities. The bow and arrow is one of the oldest technologies created by humankind, with archaeological evidence suggesting that the first bows appeared in the Upper Paleolithic period, probably more than 20,000 years ago [4].

The first uses of the bow and arrow were hunting animals, protection against predators, tribal warfare, and food survival. From the XV and XVI centuries onwards, the development of firearms gradually reduced the military importance of the bow and arrow [4]. In the XVIII and XIX centuries, archery began to transform into a recreational and sporting activity, mainly in England, with important advances occurring in materials, precision and sporting standardization, culminating in the model used from the 1972 Munich Olympic Games onwards [5]. The bow and arrow used in modern Olympic competitions is the result of a long technological evolution that began with primitive wooden bows used for hunting and warfare [5]. Analogy and similarity

involve a structural alignment or mapping between various domains in life. Analogies involving materials, instruments, and techniques used across different fields of medicine constitute valuable cognitive and educational tools for scientific reasoning, knowledge integration, problem-solving, and the development of conceptual and practical understanding in medical practice [6]. The objective of this article was to establish a biomechanical and conceptual analogy between the spinal anesthesia needle and the competitive archery arrow, emphasizing principles of precision, penetration, stability, and safety related to access to the subarachnoid space.

Comparison Between a Bow Arrow and a Spinal Needle

The comparison between an archery arrow and a spinal needle arose from the observation of possible mechanical and functional similarities between both devices. There are several analogies between them, especially when analyzing stability, flexibility, precision, and penetration capacity. The comparison is interesting from both a physical and biomechanical point of view (Table 1). The specifications of the arrow used in archery competitions are presented alongside those of the spinal needle, and there are numerous correlations between these two components, one belonging to a sporting discipline and the other to a type of anesthesia in the subarachnoid space (Figures 1 & 2). The needles used for spinal anesthesia have specific characteristics that influence the ease of puncture, CSF flow, and success rate, and should prevent complications, especially post-dural puncture headache (PDPH), and its measurement is in gauge (G) [7,8]. The gauge indicates the outer diameter of the needle, and the higher the G number, the finer the needle, and there are two types of points: cutting or pencil point [7,8]. Archery competitions utilize the recurve bow, standardized by World Archery, composed of recurve limbs, a metal riser, sights, stabilizers, carbon or aluminum-carbon arrows, and are contested over an official distance of 70 meters [9]. Both archery arrows and spinal needles can break or bend during use. Arrows used in archery can break, crack, or bend during training and competitions, although this is uncommon with modern carbon or aluminum-carbon equipment. Damage usually occurs due to repeated impact against targets, collision between arrows, misfires, contact with hard surfaces, or structural flaws in the material [10]. Several reports in the literature have demonstrated that spinal needles may bend or even fracture during use, particularly those with smaller gauges [11,12].

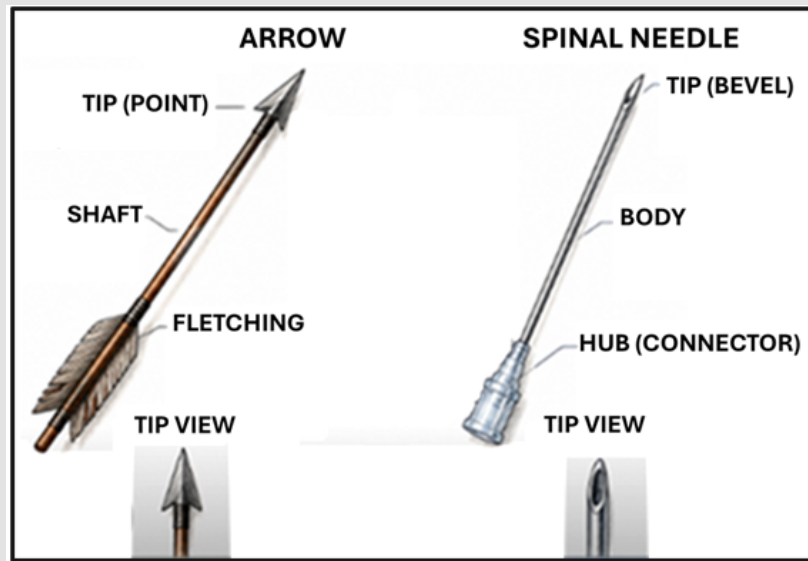


Figure 1: I draw the arrow and spinal needle with the help of AI.

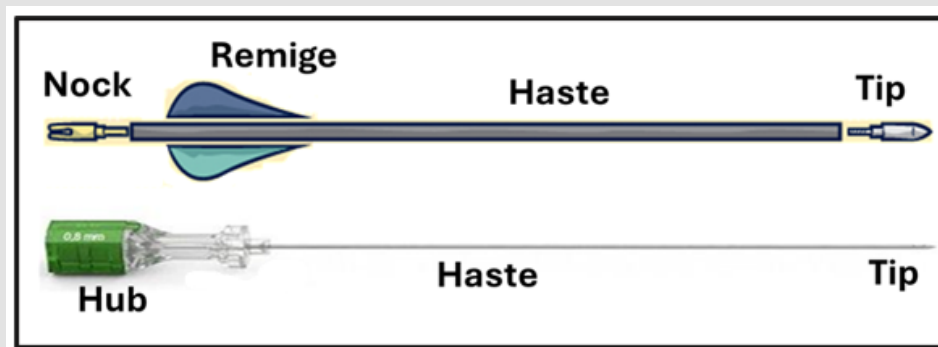


Figure 2: Comparison between an arrow and a spinal needle.

Table 1: Difference between archery competition and spinal anesthesia.

Aspect	Arrow	Spinal Needle
Function	Target colored circles	Subarachnoid space
Position	Standing	Standing / Seated
Distance target	70 m	4 - 6 cm
Goal	Circlers 1 to 10	Access the CSF
Fire	Arch	Anesthesiologist hand
Stability	Maintains stable trajectory	Design for control and precision
Contact	Nock	Hub
Haste	Aluminum	Steel
Tip	Sharp triangular	Sharp beveled

Length	66-81 cm	89-120 mm
Diameter	~4.2-9.3 mm (6G- >1G)	22G, 25G, 26G, 27G, 29G
Safety Equipment	Finger tab	Asepsis / Antisepsis
	Tab brace	Gloves
Precision Accessories	Chest protector	Mask and Cap
	Scope	Marking the desired space
	Stabilizer	Infiltration path
	Pull Clicker	Experience with time
Break or Bend in use	Yes (Ref. 9)	Yes (Ref. 10,11)
Goal	To target efficiently	To access the CSF precisely

Safety for Use of the Archery

The main safety reasons for the standardized use of arrows in the sport of archery are related to the protection of the athlete, referees, the public and the integrity of the equipment [13]. In competitions organized by World Archery, arrows follow strict manufacturing and inspection standards [13]. The main safety considerations during competitions or even training are:

- a) To avoid fractures or breakage of the arrow;
- b) To ensure stability and predictability of flight;
- c) To prevent damage to the bow;
- d) Collective safety during competitions;
- e) Reduction of accidental punctures.

With these measures, the risk of complications during competitions can be significantly reduced.

Safety for Use of Spinal Needles

An editorial demonstrated the four possible positions used to access the subarachnoid space with a spinal needle, and the presence of CSF to confirm it is in the correct location [14]. Beyond a merely technical aspect, the article reinforces the need for extreme caution when manipulating this anatomical compartment, considering that the spinal cord and its neural structures are protected by a complex osteo-ligamentous framework extending from the skull to the coccyx [15]. Therefore, access to the subarachnoid space should be regarded as a procedure of high technical and biological responsibility, requiring precision, rigorous anatomical knowledge, technical expertise, and strict adherence to safety principles in anesthesiology. The administration of substances into this compartment cannot occur empirically or indiscriminately, particularly regarding drugs not specifically approved for intrathecal use, given the potential risks of neurotoxicity, permanent neurological injury, chemical arachnoiditis, infections, and other severe complications. As in high-precision sports, in which small structural or technical failures may result in significant harm, the use of spinal needles requires standardization, quality control of materials, adequate training, and continuous vigilance regarding both procedural safety and the agents administered into the neuraxis.

Conclusion

The technological evolution of modern archery demonstrates that precision, standardization, training, and safety are inseparable elements in any activity involving the controlled direction of a penetrating object. In this context, the analogy between the arrow used in archery and the needle employed in spinal anesthesia goes beyond a simple mechanical comparison, acquiring important technical and conceptual significance. Both instruments are designed to reach a specific target with maximum precision, minimal structural deformation, and the least possible trauma to the tissues traversed. However,

unlike sport, in which the target is inanimate, and all safety measures are rigorously applied to protect athletes, referees, and the public, neuraxial anesthesia involves direct access to one of the most biologically delicate and sensitive structures of the human body: the subarachnoid space and the central nervous system. This compartment is anatomically protected by the vertebral column and specialized biological barriers, and its violation requires absolute technical, scientific, and ethical rigor. Therefore, the use of spinal needles must necessarily be associated with strict adherence to safety protocols, quality control of materials, anatomical expertise, continuous training, and the exclusive use of substances proven to be safe and approved for intrathecal administration. The trivialization of neuraxial access or the empirical use of non-validated agents contradicts fundamental principles of patient safety and the very scientific evolution of modern anesthesiology.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and Design: Luiz Eduardo Imbelloni, José Roberto de Rezende Costa, Richa Chandra, Anna Lúcia Calaça Rivoli, Sylvio V. Lemos Neto.

Acquisition, Analysis, or Interpretation of Data: Luiz Eduardo Imbelloni, José Roberto de Rezende Costa, Richa Chandra, Anna Lúcia Calaça Rivoli, Sylvio V. Lemos Neto, Antonio Fernando Carneiro.

Drafting of the Manuscript: Luiz Eduardo Imbelloni, José Roberto de Rezende Costa, Richa Chandra, Anna Lúcia Calaça Rivoli, Sylvio V. Lemos Neto, Grace Haber, Sara Pereira Lima Soares de Sá, Antonio Fernando Carneiro.

Critical Review of the Manuscript for Important Intellectual Content: Luiz Eduardo Imbelloni, José Roberto de Rezende Costa, Richa Chandra, Anna Lúcia Calaça Rivoli, Sylvio V. Lemos Neto, Grace Haber, Sara Pereira Lima Soares de Sá, Antonio Fernando Carneiro.

Supervision

Luiz Eduardo Imbelloni.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2026.65.010253

Luiz Eduardo Imbelloni. Biomed J Sci & Tech Res



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