

Radial Nerve Anatomy in the Arm and Implications for Minimally Invasive Humeral Plating: A Cadaveric Study

Doni R Praveen Kumar¹, Santanu Mallik², Kumaresan M², Julie Christy³, Gunapriya Raghunath³

¹Assistant Professor, Department of Anatomy, Rajalakshmi Medical College Hospital and Research Institute, Rajalakshmi Health City, Pennalur, Kancheepuram, Tamil Nadu, India. ²Associate Professor, Department of Anatomy, Rajalakshmi Medical College Hospital and Research Institute, Rajalakshmi Health City, Pennalur, Kancheepuram, Tamil Nadu, India. ³Associate Professor, Department of Anatomy, Rajalakshmi Medical College Hospital and Research Institute, Rajalakshmi Health City, Pennalur, Kancheepuram, Tamil Nadu, India. ³Professor & HOD, Department of Anatomy, Rajalakshmi Medical College Hospital and Research Institute, Rajalakshmi Health City, Pennalur, Kancheepuram, Tamil Nadu, India

Abstract

Background: Radial nerve (RN) injury is a major complication in humeral shaft fixation, particularly during minimally invasive plate osteosynthesis (MIPO), where direct visualization is limited. Reliable surface landmarks and hole-specific risk awareness may reduce iatrogenic injury. The objective is to define landmark-based RN localization in the arm and to identify proximal screw-hole levels associated with increased RN/profunda brachii injury risk during anterolateral humeral plating. **Material and Methods:** This original cadaveric study included two cohorts: a landmark cohort of 17 upper limbs and a plating cohort of 18 humeri. In the landmark cohort, the RN was localized using the deltoid tuberosity (DT) and brachioradialis origin (BR). Distances (DT–BR, DT–RN, RN–BR) were measured and expressed as normalized ratios (DT–RN/DT–BR; RN–BR/DT–BR). Halves and thirds categorized RN position along DT→BR. In the plating cohort, proximal screw holes (1st–4th) were assessed for RN/profunda brachii contact/penetration, reported as n/N and percentage, with associated relative distance ratios and distance-to-bundle metrics where available. **Results:** Mean DT–BR was 81.83 ± 14.86 mm; mean DT–RN was 48.88 ± 7.83 mm; and mean RN–BR was 32.95 ± 10.17 mm. The mean DT–RN/DT–BR ratio was 0.60 ± 0.07 (range 0.49–0.72). The RN was located in the middle third of DT→BR in 14/17 (82.35%) and in the distal third in 3/17 (17.65%), with 0/17 in the proximal third; by halves, 15/17 (88.24%) were in the distal half. In the plating cohort, injury risk peaked at the 2nd proximal hole (relative ratio 0.56) with 100% injury (18/18); adjacent holes also showed substantial injury incidence (66.67% at ratio 0.52; 44.44% at ratio 0.60). **Conclusion:** The RN can be anticipated along the DT→BR corridor—most often in the distal two-thirds—with clinically relevant variability. During anterolateral plating, injury risk is strongly screw-hole-dependent, with a marked danger zone near the ~0.56 ratio level. These findings support targeted nerve awareness, strict depth control, and selective far-cortex avoidance at high-risk screw-hole levels during humeral MIPO.

Keywords: Radial nerve; humerus; minimally invasive plate osteosynthesis; cadaveric study; anatomical landmarks; iatrogenic nerve injury.

Received: 03 January 2026

Revised: 25 January 2026

Accepted: 11 February 2026

Published: 17 February 2026

INTRODUCTION

Radial nerve (RN) injury is one of the most consequential complications in the management of humeral shaft fractures. While minimally invasive plate osteosynthesis (MIPO) and other limited-exposure techniques aim to preserve biology and reduce soft-tissue disruption, these approaches also reduce direct visualization of the RN, increasing the likelihood of iatrogenic injury during plate passage, drilling, and screw insertion. Preventing RN palsy, therefore, remains a central priority when choosing a fixation strategy and planning surgical corridors.^[1,2]

A major challenge is the combination of (1) anatomic variability in the RN course and its relationship to surrounding structures and (2) fixation-related risks that vary with plate position and screw-hole level. Traditional “fixed-distance” rules are often difficult to apply across patients because humeral length and soft-tissue proportions vary. In contrast, landmark-based localization using normalized ratios can improve transferability by expressing RN position as a proportion of a reproducible anatomic segment rather than an absolute measurement. Clinically useful landmarks

should be superficial, easily identifiable, and relevant to the limited approaches used in MIPO. The deltoid tuberosity (DT) and the origin of brachioradialis (BR) serve as such landmarks. They may allow the RN to be predicted along the DT→BR segment, supporting targeted incision planning and safer dissection when nerve identification is required.^[3,4]

In addition to anatomic localization, surgeons must understand where fixation is most hazardous. Even when the RN course is broadly anticipated, the risk of injury is not uniform across all screw holes. Certain hole levels may place drills and screws closer to the RN/profunda brachii complex, especially when

Address for correspondence: Dr. Doni R Praveen Kumar, Assistant professor, Department of Anatomy, Rajalakshmi Medical College Hospital and Research Institute, Rajalakshmi Health City, Pennalur, Kancheepuram, Tamil Nadu, India.
E-mail: donipraveen66@gmail.com

DOI:
10.21276/amt.2026.v13.i1.370

How to cite this article: Kumar DRP, Mallik S, Kumaresan M, Christy J, Raghunath G. Radial Nerve Anatomy in the Arm and Implications for Minimally Invasive Humeral Plating: A Cadaveric Study. *Acta Med Int.* 2026;13(1):458-462.

bicortical purchase is attempted. A hole-specific risk map can therefore complement landmark localization by identifying predictable “danger zones” where technical modifications—such as strict drill-depth control, guarded drilling, and selective far-cortex avoidance—may reduce injury risk.^[5,6] This study aimed to provide a practical, operative framework for RN protection during humeral MIPO by combining landmark-based RN localization (using DT and BR) with construct-based, screw-hole-specific risk mapping and distance-to-bundle measurements. By translating these findings into normalized ratios, distribution zones, and hole-level risk patterns, this work seeks to strengthen surgical planning and support safer execution of minimally invasive humeral fixation.

MATERIALS AND METHODS

This study was conducted as an original cadaveric anatomical investigation to quantify radial nerve (RN) localization using reproducible surface landmarks and to evaluate screw-hole-specific risk of RN/profunda brachii injury during anterolateral humeral plating. The protocol was structured into two linked components: a landmark-based localization cohort and a plating cohort, enabling interpretation of both anatomic position and fixation-related hazard within a consistent study framework.

Specimens and cohorts: Cadaveric upper-limb specimens were evaluated in two cohorts. The landmark cohort included 17 upper limbs used to determine RN position relative to the deltoid tuberosity (DT) and the origin of brachioradialis (BR). The plating cohort included 18 humeri used to assess RN/profunda brachii proximity and injury/contact patterns at defined proximal screw-hole levels during standardized anterolateral plate fixation. When specimen demographic variables were unavailable, analyses were performed without stratification, as shown in [Figure 1].

Landmark identification and nerve localization: In the landmark cohort, DT and BR origin were identified as reproducible reference points. After exposing and confirming the RN, linear measurements were obtained in millimetres: DT–BR (distance between DT and BR origin), DT–RN (distance from DT to the point where the RN was encountered), and RN–BR (distance from the RN to BR origin). To reduce the effect of limb-size variability and enable standardized intraoperative interpretation, the RN position was expressed using normalized ratios DT–RN/DT–BR and RN–BR/DT–BR. For clinically oriented zoning, RN location along DT→BR was also categorized into thirds (proximal, middle, distal) and halves (proximal half, distal half).

Plating protocol and screw-hole risk assessment: In the plating cohort, an anterolateral humeral plate was applied according to a standardized protocol, and proximal screw holes were evaluated at the 1st through 4th proximal levels as defined in the dataset. For each screw-hole level, the primary outcome was injury/contact involving the RN and/or profunda brachii complex, recorded as the number of injuries per total tested (n/N) and as a percentage. A relative distance ratio was recorded to express the hole position in a

normalized form. Where available, distance-to-bundle measurements were recorded in millimetres as the closest distance and longitudinal distance (each reported as mean ± SD). Based on observed injury incidence, screw-hole levels were categorized for operative interpretation (e.g., risky vs dangerous) in accordance with the dataset definitions.

Outcomes: Primary outcomes included landmark-based RN localization (absolute distances and normalized ratios), frequency distribution of RN position along DT→BR by halves and thirds, and screw-hole-specific injury/contact incidence with corresponding risk categorization. Secondary outcomes included distance-to-bundle metrics (closest and longitudinal distances) for screw-hole levels where these measurements were available.

Statistical analysis: All analyses were descriptive. Continuous variables were summarized as mean ± standard deviation and range (minimum–maximum). Categorical variables were summarized as counts and percentages. Visualizations were generated to represent normalized RN position, distribution of RN location by thirds, and screw-hole injury incidence, including overlapped plots combining injury incidence with distance-to-bundle metrics where appropriate.

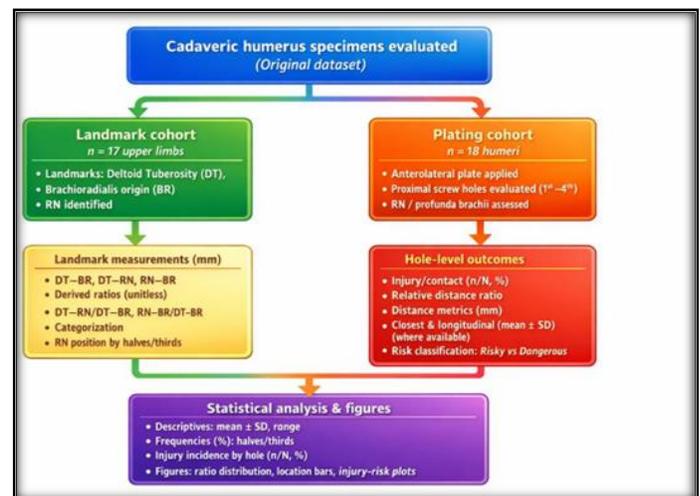


Figure 1: Study workflow for cadaveric landmark localization and screw-hole risk assessment of the radial nerve

[Figure 1] Flow diagram showing the study design and analysis pipeline. Cadaveric humerus specimens were evaluated in two cohorts: a landmark cohort (n = 17 upper limbs) using deltoid tuberosity (DT) and brachioradialis origin (BR) to localize the radial nerve (RN) with distance measurements and normalized ratios, and a plating cohort (n = 18 humeri) assessing proximal screw-hole-specific RN/profunda brachii injury/contact, relative distance ratios, and distance-to-bundle metrics where available. Outputs were summarized using descriptive statistics and presented as ratio distributions, location figures, and injury-risk figures.

RESULTS

Landmark-based localization of the radial nerve: To provide a reproducible, size-independent method for anticipating the radial nerve (RN) during minimally invasive exposure, the RN position was quantified using the deltoid tuberosity (DT) and the

brachioradialis (BR) origin as surface landmarks. Absolute distances and normalized ratios were analysed in 17

specimens, followed by categorical mapping of RN position along the DT→BR segment.

Table 1: Demographic characteristics distribution

A) Absolute distances (mm)					
Measurement	n	Mean (mm)	SD (mm)	Min (mm)	Max (mm)
DT-BR	17	81.83	14.86	60.05	113.67
DT-RN	17	48.88	7.83	35.08	60.27
RN-BR	17	32.95	10.17	21.83	57.91
B) Normalized position ratios (unitless)					
Ratio	n	Mean	SD	Min	Max
DT-RN / DT-BR	17	0.60	0.07	0.49	0.72
RN-BR / DT-BR	17	0.40	0.07	0.28	0.51

DT-BR = distance from deltoid tuberosity to brachioradialis origin; DT-RN = distance from deltoid tuberosity to radial nerve; RN-BR = distance from radial nerve to brachioradialis origin. Ratios normalize RN position along DT→BR to reduce limb-size effects ($DT-RN/DT-BR + RN-BR/DT-BR \approx 1$).

The RN was typically encountered at approximately 60% of the DT→BR distance measured distally from DT, with measurable inter-individual variability (DT-RN/DT-BR range 0.49–0.72). This supports use of the DT→BR segment as a practical landmark corridor when exposure is limited, while emphasizing the need for cautious exploration because extremes deviate substantially from the mean [Figure 2].

Table 2: variables included for landmark localization and construct-based risk mapping.

Categorical mapping of RN position along the DT→BR segment To translate ratios into operative planning zones, the DT→BR segment was divided into thirds and halves, and RN location frequency was summarized.

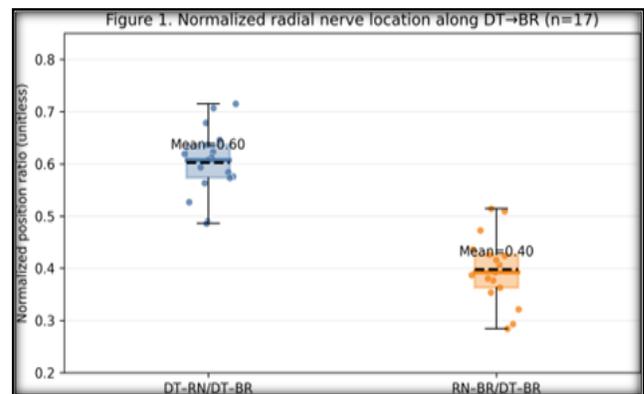


Table 2: Distribution of RN location along DT→BR (n = 17)

A) By thirds		
Segment (thirds)	n	%
Proximal 1/3	0	0.00
Middle 1/3	14	82.35
Distal 1/3	3	17.65
B) By halves		
Segment (halves)	n	%
Proximal 1/2	2	11.76
Distal 1/2	15	88.24

“Thirds” and “halves” refer to equal subdivisions of the linear DT→BR distance. Percentages are calculated from n=17.

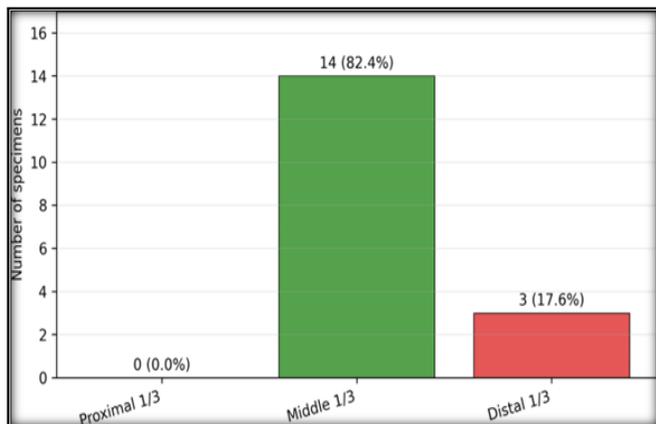


Figure 3: Distribution by thirds is summarized visually

The RN demonstrated strong clustering in the middle third (82.35%) and distal half (88.24%) of DT→BR, with no specimens in the proximal third. Practically, this indicates that the RN is most likely encountered in the distal two-thirds of the DT→BR segment; however, a minority (11.76%) positioned the RN in the proximal half, supporting a cautious approach even when operating more proximally.

Construct-based screw-hole risk mapping in anterolateral plating: Because clinical risk during MIPO depends not only on nerve course but also on implant geometry and screw placement, screw-hole-specific injury/contact incidence was summarized from 18 humeri in a standardized anterolateral plating. Distance-to-bundle metrics (where available) were added to contextualize “risky” levels.

Table 3: Screw-hole risk mapping and distance-to-bundle metrics (n = 18)

Screw hole (proximal)	Relative distance ratio	Injuries (n)	Total (N)	Injury %	Risk category	Longitudinal distance (mean ± SD), mm	Closest distance (mean ± SD), mm
4 th proximal	0.64	2	18	11.11	Risky	29.19 ± 16.44	24.44 ± 14.63
3 rd proximal	0.60	8	18	44.44	Risky	18.69 ± 15.63	15.39 ± 13.31
2 nd proximal	0.56	18	18	100.00	Dangerous	—	—
1 st proximal	0.52	12	18	66.67	Risky	12.30 ± 5.13	10.75 ± 4.86

Relative distance ratio indicates the screw-hole position expressed as a normalized proportion along the construct’s reference length (unitless). “Injury” refers to contact/penetration involving the RN and/or profunda brachii in the simulated construct assessment. Distance metrics are reported where available as (i) longitudinal distance along the humerus and (ii) closest-plane distance to the neurovascular bundle; “—” indicates not reported in the distance summary for that hole.

Risk peaked sharply at the 2nd proximal hole (ratio 0.56) with 100% injury (18/18), defining a clear danger zone for this construct. Adjacent holes also demonstrated clinically important injury incidence (66.67% at ratio 0.52; 44.44% at ratio 0.60), indicating that the hazard extends beyond a single point. Where distance data were available, mean closest distances were often small (e.g., 10.75 ± 4.86 mm at the 1st proximal hole), and variability was large, supporting conservative techniques such as strict drill-stop control and avoidance of far-cortex violation in high-risk zones.

cautious exploration strategy: DT→BR serves as a reliable corridor for anticipating the RN, but confirmation by careful dissection remains essential, particularly when exposure is minimal or when fracture displacement is present.

To improve operative usability, this study translated ratios into location zones. When DT→BR was divided into thirds, the RN clustered in the middle third in 82.35% of specimens and in the distal third in 17.65%, with no specimens in the proximal third. When divided into halves, the RN lay in the distal half in 88.24% of specimens. These distributions provide a practical interpretation: during MIPO planning, the RN is most likely encountered in the distal two-thirds of DT→BR, particularly in the middle third. Nonetheless, the presence of RN location in the proximal half in 11.76% underscores that “low probability” is “no risk,” and surgical caution should extend beyond the most common zone.^[11]

The construct-based analysis demonstrates that RN risk is not uniform along the plate. In the anterolateral plating, the 2nd proximal hole (relative distance ratio 0.56) showed 100% injury/contact (18/18), defining a clear construct-specific danger zone. Adjacent levels also carried high injury incidence (66.67% at a ratio of 0.52; 44.44% at a ratio of 0.60), implying that risk extends across a band rather than a single point. Where distance-to-bundle metrics were available, mean closest distances were small, and variability was large, indicating that even “risky” holes may be near the RN/profunda brachii complex in some specimens. Clinically, these results support conservative technical modifications in high-risk regions: strict drill-stop control, drill sleeves, careful trajectory, and preference for unicortical fixation or far-cortex avoidance when appropriate—especially near the ratio-defined danger zone.^[12]

This study also reinforces an important anatomic caution relevant to limited exposure: the dorsal humeral region can contain multiple parallel structures (RN with accompanying vessels/branches). Under MIPO conditions, misidentification is possible if only a single structure is expected. Accordingly, protection strategies should consider the entire neurovascular bundle, and when uncertainty exists, extending exposure to definitively identify and protect the RN may be safer than continuing percutaneously.^[13]

Several limitations should be acknowledged. The analysis is based on cadaveric and construct data; fracture displacement, patient positioning, soft-tissue swelling, and alternative implants may alter relationships. In addition, risk mapping is implant- and technique-specific, and the reported danger zone may shift with different plates or approaches. Despite these limitations, integrating normalized landmark localization with construct-

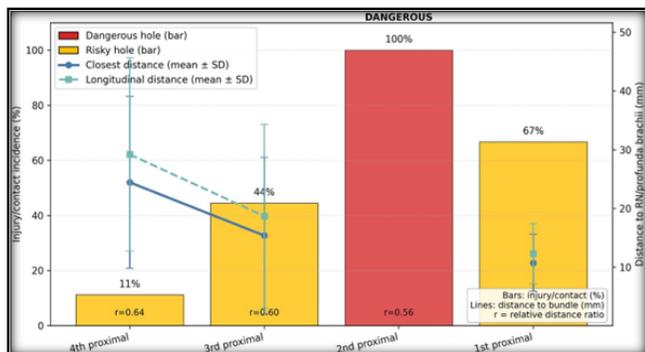


Figure 4: Screw-hole-specific radial nerve/profunda brachii injury incidence and distance-to-bundle metrics in anterolateral plating (n = 18).

DISCUSSION

This study evaluated landmark-based localization of the radial nerve (RN) and construct-based screw-hole risk mapping to generate practical guidance for humeral minimally invasive plate osteosynthesis (MIPO). The findings emphasize two complementary principles for preventing iatrogenic RN injury: first, RN position can be anticipated using reproducible surface landmarks; second, the intraoperative hazard is strongly influenced by implant configuration and the specific screw-hole level used for fixation.^[7,8]

Using the deltoid tuberosity (DT) and the origin of brachioradialis (BR) as reference points, this study found that the RN was typically encountered at approximately 60% of the DT→BR distance (mean DT–RN/DT–BR ratio 0.60). Normalization by ratio is clinically meaningful because it reduces the effect of variable arm size and provides a patient-independent way to plan limited exposures.^[9,10] However, the observed range (0.49–0.72) indicates the presence of outliers, and surgeons should avoid relying on a single “fixed distance” rule. In practice, the ratio approach supports a

based risk zones provides a coherent, transferable safety logic for humeral MIPO. It supports targeted preventive strategies in predictable high-risk regions.

CONCLUSION

This study shows that the radial nerve can be reliably anticipated along the DT→BR landmark corridor, most commonly within the distal two-thirds, and that drilling/screw risk is strongly screw-hole dependent during anterolateral plating. Combining landmark-based localization with hole-specific risk mapping supports safer humeral MIPO through targeted nerve awareness, strict depth control, and selective far-cortex avoidance in defined high-risk zones.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Gardner M.J., Griffith M.H., Lorch D.G. Helical plating of the proximal humerus. *Injury*. 2005;36:1197–1200. doi: 10.1016/j.injury.2005.06.038.
- Rancan M., Dietrich M., Lamdark T., Can U., Platz A. Minimal invasive long PHILOS®- plate osteosynthesis in metadiaphyseal fractures of the proximal humerus. *Injury*. 2010;41:1277–1283. doi: 10.1016/j.injury.2010.07.235.
- Sakoma Y., Sano H., Shinozaki N., Itoigawa Y., Yamamoto N., Ozaki T. Anatomical and functional segments of the deltoid muscle. *J Anat*. 2010;218:185–190. doi: 10.1249/MSS.0b013e31816073fb.
- Lee H.-J., Oh C.-W., Oh J.-K., Apivatthakakul T., Kim J.-W., Yoon J.P. Minimally invasive plate osteosynthesis for humeral shaft fracture: a reproducible technique with the assistance of an external fixator. *Arch Orthop Trauma Surg*. 2013;133:649–657. doi: 10.1016/j.jse.2003.12.005.
- Esenyel C.Z. Relationship between axillary nerve and percutaneously inserted proximal humeral locking plate: a cadaver study. *Acta Orthop Traumatol Turc*. 2014;48:553–557. doi: 10.3944/AOTT.2014.13.0083.
- Hohmann E., Glatt V., Tetsworth K. Minimally invasive plating versus either open reduction and plate fixation or intramedullary nailing of humeral shaft fractures: a systematic review and meta-analysis of randomized controlled trials. *J Shoulder Elbow Surg*. 2016;25:1634–1642. doi: 10.1016/j.jse.2016.05.014.
- Zhao J.-G., Wang J., Meng X.-H., Zeng X.-T., Kan S.-L. Surgical interventions to treat humerus shaft fractures: a network meta-analysis of randomized controlled trials. *PLoS One*. 2017;12:e0173634. doi: 10.1371/journal.pone.0173634.s001.
- Shin Y.H., Lee Y.H., Choi H.S., Kim M.B., Pyo S.H., Baek G.H. A modified deltoid splitting approach with axillary nerve bundle mobilization for proximal humeral fracture fixation. *Injury*. 2017;48:2569–2574. doi: 10.1016/j.injury.2017.09.007.
- Moatshe G., Marchetti D.C., Chahla J., Ferrari M.B., Sanchez G., Lebus G.F. Qualitative and quantitative anatomy of the proximal humerus muscle attachments and the axillary nerve: a cadaveric study. *Arthroscopy*. 2018;34:795–803. doi: 10.1016/j.arthro.2017.08.301.
- Tetsworth K., Hohmann E., Glatt V. Minimally invasive plate osteosynthesis of humeral shaft fractures. *J Am Acad Orthop Surg*. 2018;26:652–661. doi: 10.5435/JAAOS-D-17-00238.
- Mehraj M., Shah I., Mohd J., Rasool S. Early results of bridge plating of Humerus diaphyseal fractures by MIPO technique. *Ortop Traumatol Rehabil*. 2019;21:109–118. doi: 10.5604/01.3001.0013.1915.
- Touloupakis G., Di Giorgio L., Bibiano L., Biancardi E., Ghirardelli S., Dell'Orfano M. Exploring the difficulties to improve minimally invasive application with long PHILOS plate in multifocal metadiaphyseal fractures of the proximal humerus: analysis of intraoperative procedure and clinical outcomes. *Acta Biomed*. 2019;89:532–539. doi: 10.23750/abm.v89i4.6212.
- Wen H., Zhu S., Li C., Chen Z., Yang H., Xu Y. Antegrade intramedullary nail versus plate fixation in the treatment of humeral shaft fractures. *Medicine*. 2019;98:e17952. doi: 10.1097/MD.0000000000017952..