

MINISTRY OF EDUCATION AND TRAINING MINISTRY OF HEALTH
HAI PHONG UNIVERSITY OF MEDICINE AND PHARMACY



TRINH DINH THANH

**IMAGING CHARACTERISTICS AND SURGICAL OUTCOMES
OF CLOSED SCAPULAR FRACTURES**

Major: Surgery

Code: 9720104

SUMMARY OF THE DOCTORAL DISSERTATION IN MEDICINE

HAI PHONG - 2026

**THIS DISSERTATION WAS COMPLETED AT:
HAI PHONG UNIVERSITY OF MEDICINE AND PHARMACY**

Supervisors::

- 1.Assoc. Prof. Nguyen Manh Khanh, MD, PhD
- 2.Assoc. Prof. Pham Van Thuong, MD, PhD

Reviewer 1:

Reviewer 2:

Reviewer 3:

The dissertation will be defended before the University-level
Doctoral Dissertation Examination Committee at Hai Phong
University of Medicine and Pharmacy.

At: a.m./p.m., on, 2026.

The dissertation is available at:

- National Library of Viet Nam
- Library of Hai Phong University of Medicine and Pharmacy

**LIST OF SCIENTIFIC PUBLICATIONS RELATED TO THE
DISSERTATION**

1. Trinh DD, Nguyen MK, Pham VT. **Imaging Characteristics of Closed Scapular Fractures on Plain Radiography and Computed Tomography.** *Journal of Community Medicine.* 2026;67(5):122–127.
2. Trinh DD, Nguyen MK, Pham VT. **Outcomes of Open Reduction and Internal Fixation of Closed Scapular Fractures Using Locking Plates.** *Journal of Community Medicine.* 2026;67(5):149–153.
3. Trinh DD, Nguyen MK, Pham VT. **Factors Affecting Functional Outcomes After Surgical Fixation of Scapular Fractures.** *Journal of Community Medicine.* 2026;67(English Version No. 1). ISSN 2354-0613.

INTRODUCTION

The scapula plays a pivotal role in the anatomy and function of the shoulder girdle. It serves as the attachment site for numerous muscles and contributes significantly to the stability and range of motion of the upper extremity. Scapular fractures are relatively uncommon injuries, typically resulting from high-energy trauma and frequently associated with multiple injuries. Although their incidence is low, fractures involving the scapular neck and glenoid may lead to persistent pain, restricted shoulder motion, and impaired upper-limb function if not accurately diagnosed and appropriately treated.

Diagnostic imaging plays a crucial role in the evaluation of scapular fractures and in determining the optimal treatment strategy. Conventional radiography is the initial imaging modality but has important limitations because of the complex anatomy of the shoulder girdle and the overlap of adjacent osseous structures, which may result in missed or underestimated injuries. In contrast, multidetector computed tomography with three-dimensional reconstruction (3D CT) provides a more accurate assessment of fracture location, displacement, articular involvement, and morphological parameters, including the glenopolar angle (GPA), lateral border offset (LBO), and angular deformity. These parameters improve fracture classification, facilitate surgical decision-making, and assist in preoperative planning.

Advances in fixation techniques and a better understanding of shoulder girdle biomechanics have expanded the indications for surgical management of displaced and unstable scapular fractures. However, studies on scapular fractures in Vietnam remain limited and are mainly single-center reports with relatively small sample sizes. To date, no comprehensive study has systematically evaluated the roles of conventional radiography and computed tomography in fracture diagnosis, classification, assessment of morphological parameters related to surgical indications, and surgical outcomes at major trauma centers.

Based on these considerations, we conducted the study entitled **“Imaging Characteristics and Surgical Outcomes of Closed Scapular Fractures”** with the following objectives:

1. *To describe the imaging characteristics of closed scapular fractures at Viet Duc University Hospital and Viet Tiep Friendship Hospital.*
2. *To evaluate the surgical outcomes of closed scapular fractures at Viet Duc University Hospital and Viet Tiep Friendship Hospital.*

GENERAL INFORMATION ABOUT THE DISSERTATION

1. Structure of the Dissertation

The dissertation consists of 148 pages, including:

- Introduction: 2 pages
- Chapter 1. Literature Review: 38 pages
- Chapter 2. Subjects and Methods: 30 pages
- Chapter 3. Results: 28 pages
- Chapter 4. Discussion: 45 pages
- Conclusions: 2 pages
- Recommendations: 1 page

The dissertation contains 45 tables, 33 figures and charts, and 98 references (Vietnamese and English).

2. Novel Contributions of the Dissertation

- The dissertation systematically describes the imaging characteristics of closed scapular fractures on conventional radiography and computed tomography (CT), and quantitatively compares the two imaging modalities in detecting fractures, classifying fractures according to the AO/OTA classification, and evaluating important morphological parameters, including the Glenopolar Angle (GPA), Lateral Border Offset (LBO), angular deformity, and glenoid involvement.
- The dissertation clarifies the role of CT in assessing fracture severity and determining imaging parameters relevant to surgical indications and preoperative planning. The findings demonstrate that CT provides more accurate diagnostic information than conventional radiography, thereby improving fracture

classification, treatment decision-making, and surgical planning for closed scapular fractures.

- The dissertation evaluates the clinical outcomes of open reduction and internal fixation using locking plates for the treatment of closed scapular fractures. The results demonstrate that this technique achieves satisfactory anatomical reduction, a high fracture union rate, excellent restoration of shoulder function, and significant improvement in patients' quality of life. These findings provide additional scientific evidence and practical guidance for the surgical management of closed scapular fractures in Vietnam.

CHAPTER 1. LITERATURE REVIEW

1.1. Anatomy and Biomechanics of the Scapula

The scapula is a flat, triangular bone located on the posterior aspect of the thoracic cage. Together with the clavicle, it forms the shoulder girdle and plays a crucial role in connecting the upper limb to the trunk. Anatomically, the scapula consists of the body, neck, glenoid, scapular spine, acromion, and coracoid process. The glenoid articulates with the humeral head to form the glenohumeral joint, which has the greatest range of motion in the human body. In addition, the scapula serves as the origin and insertion for numerous important muscles, including the supraspinatus, infraspinatus, subscapularis, teres minor, teres major, deltoid, and other periscapular muscles. The coordinated action of these muscles provides dynamic stability to the shoulder joint and enables upper-limb movements such as abduction, flexion, extension, rotation, and elevation.

From a biomechanical perspective, the scapula, clavicle, and surrounding ligamentous structures form the Superior Shoulder Suspensory Complex (SSSC), which is essential for maintaining the stability of the shoulder girdle. Disruption of one or more components of the SSSC may alter the normal anatomical alignment of the shoulder, impair upper-limb function, and increase the risk of chronic pain or persistent limitation of shoulder motion following injury. Therefore, comprehensive assessment of scapular fractures and associated injuries is essential for selecting the most appropriate treatment strategy.

1.2. Characteristics of Scapular Fractures

Scapular fractures are relatively uncommon injuries, accounting for approximately 0.5–1% of all fractures and 3–5% of shoulder girdle fractures. Owing to the thick muscular envelope surrounding the scapula and its considerable mobility, these fractures usually occur only after high-energy

trauma. Consequently, most patients sustain scapular fractures following motor vehicle accidents, occupational injuries, or falls from height.

Because of the high-energy mechanism of injury, scapular fractures are frequently associated with multiple concomitant injuries, including rib fractures, hemothorax, pneumothorax, spinal injuries, clavicular fractures, proximal humeral fractures, and other upper-extremity injuries. In patients with multiple trauma, priority is often given to the management of life-threatening conditions, which may result in missed scapular fractures unless careful clinical examination and appropriate imaging studies are performed.

Several classification systems have been developed for scapular fractures. The AO/OTA classification (2018) is currently the most widely adopted because it provides a comprehensive description of fracture location and morphology while facilitating standardized treatment indications and comparison among clinical studies. For glenoid fractures, the Ideberg classification remains widely used to assess the extent of articular involvement and to guide treatment selection. In addition, anatomical classification based on fracture location—including fractures of the scapular body, neck, glenoid, scapular spine, acromion, and coracoid process—plays an important role in treatment decision-making and functional prognosis.

In recent years, advances in diagnostic imaging, fixation techniques, and the understanding of shoulder biomechanics have substantially changed the management of scapular fractures. Whereas conservative treatment was previously recommended for most patients, surgical indications have progressively expanded to include fractures with significant displacement, articular involvement, disruption of the Superior Shoulder Suspensory Complex (SSSC), or deformities likely to impair shoulder function. Therefore, accurate evaluation of fracture morphology using modern imaging

modalities has become a key factor in selecting the optimal treatment strategy.

1.3. Imaging Evaluation of Scapular Fractures

Diagnostic imaging plays a pivotal role in the detection, characterization, classification, and treatment planning of scapular fractures. In clinical practice, conventional radiography remains the initial imaging modality because it is readily available, cost-effective, and allows rapid assessment at the time of patient presentation. Standard radiographic views include the anteroposterior (AP), scapular Y, Grashey, and axillary views. Conventional radiographs are useful for identifying most fractures of the scapular body, providing a preliminary assessment of fracture displacement, and detecting certain associated shoulder injuries.

However, because the scapula is deeply situated within the surrounding musculature and overlies the thoracic cage, conventional radiography has important limitations in evaluating complex fracture patterns. Fractures involving the scapular neck, glenoid, coracoid process, acromion, or multifragmentary fractures are frequently underestimated or missed on plain radiographs, resulting in inaccurate assessment of fracture severity and potentially inappropriate treatment decisions. Therefore, many authors recommend that conventional radiography should be considered primarily as an initial screening tool, with computed tomography (CT) performed whenever complex fractures are suspected or surgical treatment is contemplated.

Currently, multidetector computed tomography with three-dimensional reconstruction (3D CT) is regarded as the reference imaging modality for comprehensive evaluation of scapular fractures. CT provides detailed multiplanar visualization of fracture morphology, allowing accurate assessment of fracture location, fragment number, displacement, articular

involvement, and the relationship between fracture fragments and adjacent anatomical structures. Three-dimensional reconstruction enables surgeons to better understand fracture configuration, select the most appropriate surgical approach, determine optimal implant positioning, and formulate an individualized preoperative surgical plan. Several studies have demonstrated that CT changes fracture classification or alters treatment strategy in approximately 25–35% of patients compared with assessment based on conventional radiography alone.

One of the major advantages of CT is its ability to accurately quantify morphological parameters that are important for evaluating fracture severity and determining surgical indications. The Glenopolar Angle (GPA) reflects the relationship between the glenoid and the scapular body and is an important indicator of scapular neck deformity. A reduced GPA is associated with shoulder girdle instability and poorer functional outcomes if anatomical alignment is not restored. The Lateral Border Offset (LBO) measures displacement of the lateral border of the scapula and is widely used to evaluate displacement of fractures involving the scapular body and neck. Other important parameters include angular deformity, articular step-off, and the percentage of glenoid articular involvement. Thresholds such as GPA $<20^\circ$, LBO ≥ 20 mm, angular deformity $>40^\circ$, and substantial glenoid articular involvement are widely accepted as important criteria when considering surgical intervention.

Regarding fracture classification, the AO/OTA 2018 classification system is currently the most widely accepted because of its comprehensive and systematic description of scapular fracture patterns. This classification facilitates standardized communication among orthopedic surgeons, supports treatment selection, assists in prognostic assessment, and enables meaningful comparisons between clinical studies. For fractures involving the glenoid, the

Ideberg classification remains an important system for evaluating the extent of articular injury and guiding surgical management.

Overall, advances in imaging technology have considerably expanded the role of CT beyond simple fracture detection. CT not only improves diagnostic accuracy and fracture classification but also provides quantitative anatomical parameters that are essential for determining surgical indications, optimizing preoperative planning, and evaluating postoperative outcomes. Consequently, CT has become an indispensable imaging modality for the comprehensive assessment of scapular fractures, particularly in patients considered for surgical treatment.

1.4. Treatment of Scapular Fractures

The management of scapular fractures depends on the fracture location, degree of displacement, involvement of the articular surface, stability of the superior shoulder suspensory complex, and the presence of associated injuries. The treatment goal is to restore anatomical alignment, re-establish shoulder stability, facilitate early functional recovery, and limit long-term complications such as chronic pain, limited range of motion, or shoulder arthrosis.

Most fractures of the scapular body or minimally displaced fractures are managed non-operatively with brief immobilization followed by early physiotherapy. Conservative treatment typically yields good results when shoulder alignment is preserved, the superior suspensory complex remains stable, and there is no significant articular injury. A structured rehabilitation program is crucial in such cases to prevent stiffness, restore joint mobility, and rebuild muscle strength around the shoulder girdle.

In recent years, advances in imaging and fixation techniques have expanded the indications for surgery. Current recommendations rely largely on CT-based morphological criteria. Surgery is generally indicated for displaced

glenoid fractures or unstable glenohumeral joints; markedly deformed fractures of the scapular neck; scapular body fractures with substantial displacement or angular deformity beyond accepted thresholds; “floating shoulder” injuries (combined fractures affecting the superior suspensory complex); and certain fractures of the acromion or coracoid that compromise function or stability. Objective criteria such as the Glenopolar Angle (GPA), Lateral Border Offset (LBO), angular deformity, and extent of glenoid involvement are widely used to support surgical decision-making.

Improved surgical approaches and fixation devices have enhanced outcomes. The modified Judet and Brodsky approaches are commonly used for fractures of the scapular body and neck, providing good exposure while minimizing soft-tissue disruption. For glenoid fractures, the approach depends on the fracture’s location and morphology to achieve optimal anatomical reduction. Anatomical locking plates are now widely used because they offer strong fixation, conform to scapular anatomy, enable early postoperative mobilization, and reduce the risk of loss of reduction.

Rehabilitation is an integral part of treatment. Postoperatively, patients are immobilized briefly to protect the fracture, followed by controlled passive and active exercises based on the stability of the fixation. Rehabilitation aims to restore range of motion, shoulder girdle strength, and everyday function. Studies show that successful outcomes depend not only on accurate reduction and fixation but also on a structured postoperative rehabilitation program.

Overall, the current trend is toward individualized treatment, guided by comprehensive CT assessment, and tailored choice of surgical approach and fixation method to restore maximal anatomical and functional outcomes. This approach is now widely adopted in leading orthopedic trauma centers worldwide.

1.5. Current Status of Research on Scapular Fractures Worldwide and in Vietnam

Over the past two decades, advances in diagnostic imaging and internal fixation techniques have significantly improved the understanding and management of scapular fractures. International research has primarily focused on three major areas: characterization of fracture patterns using imaging modalities, establishment of surgical indications based on morphological parameters, and evaluation of surgical outcomes.

Numerous investigators, including Zlowodzki, Anavian, Armitage, Bartoníček, and their colleagues, have emphasized the essential role of computed tomography (CT), particularly three-dimensional (3D) CT reconstruction, in the diagnosis and management of scapular fractures. These studies have demonstrated that CT provides superior detection of glenoid, scapular neck, and comminuted fractures compared with conventional radiography. Furthermore, CT enables accurate quantitative assessment of important morphological parameters, including the Glenopolar Angle (GPA), Lateral Border Offset (LBO), angular deformity, and the extent of articular involvement, all of which serve as critical criteria for determining surgical indications. Along with advances in locking plate fixation systems and less invasive surgical approaches, numerous studies have shown that operative treatment can achieve satisfactory anatomical restoration and functional recovery when appropriate surgical indications are applied.

In Vietnam, research on scapular fractures remains relatively limited and has mainly consisted of single-center studies with small sample sizes. Most published studies have focused on clinical characteristics, treatment outcomes, or institutional experience with specific surgical techniques, whereas the role of modern imaging modalities has not been comprehensively investigated. Comparisons between conventional radiography and CT in

fracture detection, fracture classification, and evaluation of morphological parameters remain scarce. Moreover, few studies have explored the relationship between imaging findings and surgical decision-making or comprehensively assessed surgical outcomes based on anatomical reduction, shoulder function, and patients' quality of life.

Therefore, several important knowledge gaps remain. First, no domestic study has systematically compared conventional radiography and CT in detecting fractures, classifying injury patterns, and evaluating the morphological characteristics of closed scapular fractures. Second, the clinical value of imaging parameters such as the Glenopolar Angle (GPA), Lateral Border Offset (LBO), angular deformity, and glenoid involvement in guiding surgical indications has not been adequately investigated under Vietnamese clinical practice conditions. Third, studies evaluating the outcomes of surgical treatment for scapular fractures remain limited, are generally based on small sample sizes, and rarely provide comprehensive assessments incorporating anatomical reduction, functional recovery, health-related quality of life, and overall treatment effectiveness at major trauma centers.

To address these knowledge gaps, the present dissertation, entitled "Characteristics of Injury and Surgical Outcomes of Closed Scapular Fractures," was conducted to comprehensively evaluate the imaging characteristics of closed scapular fractures using both conventional radiography and CT, clarify the role of CT in diagnosis and surgical decision-making, and assess the outcomes of locking plate fixation performed at Viet Duc University Hospital and Viet Tiep Friendship Hospital. The findings of this study are expected to provide additional scientific evidence and practical data to improve diagnostic accuracy, optimize treatment selection, and enhance clinical outcomes for patients with closed scapular fractures in Vietnam.

CHAPTER 2: MATERIALS AND METHODS

2.1. Study Population, Setting, and Study Period

This study was conducted at Viet Duc University Hospital and Viet Tiep Friendship Hospital from September 2023 to December 2025. A total of 220 patients diagnosed with closed scapular fractures were enrolled, including 35 patients who underwent open reduction and internal fixation (ORIF) using locking plates. All patients underwent comprehensive clinical examination, digital radiography, and non-contrast 64-slice multidetector computed tomography (MDCT) with multiplanar reconstruction and three-dimensional (3D) reconstruction to evaluate fracture characteristics. Eligible patients were selected according to predefined inclusion and exclusion criteria established for each study objective.

For Objective 1, a retrospective–prospective cross-sectional descriptive study was conducted to characterize the imaging features of closed scapular fractures. Patients were included if complete clinical records, standard radiographs, and three-dimensional CT images were available. Fractures were classified according to the AO/OTA classification system. Patients with pathological fractures or old (healed or neglected) fractures were excluded from the study.

For Objective 2, a prospective longitudinal descriptive study was performed to evaluate the outcomes of surgical fixation. Patients were considered eligible for surgery if they met at least one of the following criteria: displaced fractures of the scapular body or neck with angular deformity $>40^\circ$, lateral border offset (LBO) ≥ 20 mm, or LBO >15 mm combined with angular deformity $>35^\circ$; Glenopolar Angle (GPA) $<20^\circ$; intra-articular glenoid fractures with articular step-off ≥ 4 mm or $\geq 20\%$ involvement of the glenoid articular surface; unstable double disruption of the Superior Shoulder Suspensory Complex (SSSC); or displaced fractures of the scapular processes

requiring operative treatment. Patients with pathological fractures, chronic or neglected fractures, severe multiple trauma (Injury Severity Score [ISS] ≥ 16), medical conditions precluding surgery, or inability to complete postoperative follow-up were excluded from the study.

2.2. Study Design

For Objective 1, a retrospective–prospective cross-sectional descriptive study was conducted to characterize the imaging features of closed scapular fractures.

For Objective 2, a prospective longitudinal descriptive study was performed to evaluate the outcomes of open reduction and internal fixation (ORIF) using locking plates.

The sample size was calculated using the formula for estimating a single population proportion. The minimum required sample size for Objective 1 was 139 patients; however, 220 patients were ultimately enrolled. For Objective 2, the minimum required sample size was 35 patients, and all 35 eligible patients who met the inclusion criteria during the study period were included in the analysis.

A consecutive sampling method was employed, whereby all patients meeting the predefined inclusion criteria at the two participating hospitals during the study period were consecutively recruited.

2.3. Study Materials and Procedures

All patients underwent a standardized clinical evaluation using a predefined study case report form. Digital radiographs and CT images were stored in the Picture Archiving and Communication System (PACS) and analyzed using dedicated imaging software. The following morphological parameters were measured: Glenopolar Angle (GPA), Lateral Border Offset (LBO), scapular body angulation, articular step-off, and the percentage of glenoid articular surface involvement. All imaging studies were independently reviewed by

two orthopedic surgeons, and any discrepancies were resolved by consensus before data analysis.

For patients who met the surgical indications, the operative strategy was determined according to the fracture characteristics identified on three-dimensional (3D) CT reconstruction. Surgery was performed under general endotracheal anesthesia using either the modified Judet approach or the Brodsky approach, depending on the fracture location. Open reduction and internal fixation (ORIF) was performed using anatomical locking plates to restore anatomical alignment, re-establish the stability of the shoulder girdle, and facilitate early functional rehabilitation. Following surgery, all patients received standardized postoperative management and rehabilitation according to a uniform treatment protocol.

2.4. Study Variables and Outcome Measures

The study variables were defined in accordance with the two research objectives.

For Objective 1, the variables included patients' demographic and clinical characteristics, mechanism of injury, radiographic and CT findings, fracture location, number of fracture fragments, degree of displacement, AO/OTA fracture classification, morphological parameters (Glenopolar Angle [GPA], Lateral Border Offset [LBO], scapular body angulation, and glenoid involvement), associated injuries, and the diagnostic performance of conventional radiography compared with CT in detecting scapular fractures.

For Objective 2, the variables included intraoperative characteristics (surgical approach, patient positioning, operative time, fixation method, and blood transfusion requirements), early postoperative outcomes (quality of fracture reduction, wound healing, and early complications), and late postoperative outcomes (fracture union, Constant–Murley Score, health-related quality of

life assessed using the EQ-5D-5L, late complications, and functional outcomes of the shoulder joint).

2.5. Data Collection Methods and Instruments

Data were collected using a standardized case report form, which included demographic information, clinical findings, laboratory and imaging results, operative records, and follow-up outcomes after treatment. Imaging data were measured directly on the Picture Archiving and Communication System (PACS) using dedicated imaging software. Shoulder function was assessed using the Constant–Murley Score, health-related quality of life was evaluated using the EQ-5D-5L questionnaire, and fracture union was determined based on both clinical and radiographic criteria according to established published guidelines.

2.6. Statistical Analysis

All data were coded, entered into Microsoft Excel, and analyzed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation (SD) or median with interquartile range (IQR), depending on data distribution, whereas categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using the Chi-square test, Fisher's exact test, Student's t-test, or the Mann–Whitney U test, as appropriate. Agreement between conventional radiography and CT was assessed using appropriate statistical methods. Factors associated with treatment outcomes were analyzed using univariate and multivariable regression analyses. A two-sided p-value < 0.05 was considered statistically significant.

2.7. Ethical Considerations

The study protocol was reviewed and approved by the Institutional Review Board (IRB) of Hai Phong University of Medicine and Pharmacy before study initiation. All participants received detailed information regarding the

study objectives, procedures, potential benefits, and their rights as research participants. Only patients who provided written informed consent were enrolled in the study. All personal information was anonymized and kept strictly confidential, and the collected data were used exclusively for scientific research purposes. The study did not interfere with or alter the hospitals' routine diagnostic and treatment protocols and was conducted in accordance with the ethical principles governing medical research.

CHAPTER 3: RESULTS

3.1. General Characteristics of the Study Population

This study included 220 patients with closed scapular fractures who were treated at Viet Duc University Hospital and Viet Tiep Friendship Hospital between September 2023 and December 2025. Of these, 185 patients (84.1%) received non-operative treatment, whereas 35 patients (15.9%) underwent open reduction and internal fixation (ORIF) using locking plates. Patients in the surgical group were followed prospectively for a mean duration of 13.34 ± 5.16 months (range, 6–22 months).

The mean age of the study population was 48.94 ± 15.21 years (range, 16–84 years). Patients aged 40–59 years represented the largest proportion of the cohort, followed by those aged 20–39 years, reflecting the predominance of high-energy trauma among the working-age population. Male patients accounted for 84.1% of the study population, with a male-to-female ratio of approximately 5.3:1, consistent with the epidemiological characteristics of scapular fractures, which are more common among men involved in traffic accidents and physically demanding occupations.

Road traffic accidents were the leading cause of injury, accounting for 70.0% of all cases. Other mechanisms included falls from height (13.6%),

occupational injuries, and miscellaneous causes. These findings indicate that scapular fractures are predominantly associated with high-energy trauma, consistent with the anatomical protection provided by the thick muscular envelope surrounding the scapula.

Most patients sustained associated injuries, and the majority had an Injury Severity Score (ISS) ranging from 9 to 24, reflecting the polytrauma nature of this patient population. However, among patients undergoing surgical fixation, most had an ISS <16, satisfying the study's eligibility criteria for operative treatment.

Preoperative physical status was assessed using the American Society of Anesthesiologists (ASA) Physical Status Classification. Most patients were classified as ASA I (80.9%) or ASA II (18.2%), whereas only 0.9% were classified as ASA III, indicating that the majority of patients were in stable general condition and suitable candidates for anesthesia and surgery.

The most common associated injuries included rib fractures, clavicular fractures, thoracic injuries, and other injuries involving the upper extremity. These findings further support the high-energy mechanism of injury and emphasize the importance of comprehensive evaluation in polytrauma patients to avoid missed scapular fractures.

Overall, the study population accurately reflects the epidemiological characteristics of closed scapular fractures encountered in routine clinical practice. Most patients were working-age men who sustained high-energy trauma and presented with multiple associated injuries.

3.2. Imaging Characteristics of Closed Scapular Fractures

All 220 patients underwent both conventional radiography and multidetector computed tomography (MDCT) with three-dimensional (3D) reconstruction, allowing a direct comparison of the diagnostic value of these two imaging modalities in the evaluation of scapular fractures.

**Table 3.1. Detection of Scapular Fractures on Conventional Radiography
According to Treatment Group (n = 220)**

<i>Detection of scapular fracture on conventional radiography</i>	<i>Non-operative treatment (n = 185)</i>	<i>Surgical treatment (n = 35)</i>	<i>Total (n = 220)</i>
<i>Detected</i>	123 (66.5%)	32 (91.4%)	155 (70.5%)
<i>Not detected</i>	62 (33.5%)	3 (8.6%)	65 (29.5%)
<i>Total</i>	185 (100%)	35 (100%)	220 (100%)

The results showed that conventional radiography detected scapular fractures in 155 of 220 patients (70.5%), whereas 65 patients (29.5%) had no fracture identified on plain radiographs. In contrast, computed tomography (CT) detected fractures in all 220 patients (100%), demonstrating its superior diagnostic performance for the evaluation of closed scapular fractures.

Among patients managed non-operatively, the fracture detection rate on conventional radiography was 66.5%, which was significantly lower than that in the surgical group (91.4%, $p = 0.002$). These findings suggest that markedly displaced fractures are more readily recognized on plain radiographs, whereas minimally displaced fractures and injuries involving anatomically complex regions are more likely to be overlooked when conventional radiography is used alone.

Regarding fracture location, the scapular body was the most commonly involved site, accounting for 84.5% of fractures on CT, followed by the glenoid (10.9%), coracoid process (10.5%), scapular spine (9.5%), acromion (7.7%), and scapular neck (4.5%). Compared with CT, conventional

radiography detected substantially fewer fractures involving the glenoid, scapular neck, and scapular processes, reflecting the inherent limitations of plain radiography caused by overlapping anatomical structures around the shoulder girdle.

Evaluation of fracture fragmentation showed that CT identified three or more fracture fragments in 56.4% of cases, nearly twice the proportion detected on conventional radiography (20.0%, $p = 0.007$). Conversely, conventional radiography tended to underestimate fracture complexity, classifying many injuries as simple two-fragment fractures. These findings indicate that CT provides a more comprehensive assessment of fracture morphology, particularly in comminuted and complex fracture patterns.

Fracture classification according to the AO/OTA classification system also differed substantially between conventional radiography and CT. Based on CT findings, the proportion of Type A fractures increased from 5.0% to 11.4%, Type B fractures from 52.3% to 64.1%, Type F fractures from 1.4% to 4.1%, and combined complex fracture patterns from 11.8% to 20.5%. Notably, 29.5% of fractures that could not be classified on conventional radiographs were successfully classified on CT, further emphasizing the important role of CT in fracture classification and treatment planning.

These findings indicate that CT not only improves fracture detection but also substantially changes the assessment of fracture location, fracture fragmentation, and injury complexity, thereby providing essential information for determining treatment indications and optimizing preoperative planning.

Direct comparison between conventional radiography and CT further demonstrated the superiority of CT in evaluating fracture morphology. In addition to identifying all scapular fractures, CT provided more accurate assessment of fracture location, number of fracture fragments, degree of displacement, and articular involvement. Fractures involving the glenoid,

scapular neck, coracoid process, acromion, and scapular spine were detected more frequently on CT than on conventional radiographs, highlighting the limitations of plain radiography resulting from overlapping anatomical structures of the shoulder girdle.

Among patients who underwent surgical treatment, the differences between the two imaging modalities were even more pronounced. The Glenopolar Angle (GPA) measured on CT was $33.49 \pm 9.87^\circ$, which was significantly lower than the value measured on conventional radiographs ($35.74 \pm 7.23^\circ$, $p = 0.019$). Conversely, the Lateral Border Offset (LBO) measured on CT was 18.69 ± 10.31 mm, significantly greater than the 12.60 ± 7.70 mm measured on conventional radiographs ($p < 0.001$). Similarly, the scapular body angulation was significantly greater on CT ($27.91 \pm 14.74^\circ$) than on conventional radiographs ($20.91 \pm 11.22^\circ$, $p < 0.001$).

For patients with glenoid fractures, CT also provided a more accurate assessment of articular involvement. The mean articular step-off measured on CT was 7.29 ± 4.35 mm, significantly greater than the 4.71 ± 2.14 mm measured on conventional radiographs ($p = 0.032$). Likewise, the mean percentage of glenoid articular surface involvement was $34.50 \pm 8.94\%$ on CT, compared with $22.43 \pm 8.79\%$ on conventional radiographs ($p = 0.002$). These findings indicate that conventional radiography tends to underestimate the severity of fracture displacement and articular involvement, particularly in intra-articular scapular fractures.

Analysis of imaging parameters associated with surgical indications demonstrated that several treatment criteria were more accurately identified on CT. Among patients who underwent surgical treatment, the proportion with scapular body angulation $>40^\circ$ was significantly higher than that in the non-operative group (28.6% vs. 5.9%; $p < 0.001$). Similarly, Lateral Border Offset (LBO) ≥ 20 mm was observed in 60.0% of surgically treated patients

compared with 7.6% of those managed non-operatively ($p < 0.001$). The combined criterion of LBO ≥ 15 mm and scapular body angulation $>35^\circ$ was present in 17.1% of the surgical group versus 4.3% of the non-operative group ($p = 0.004$). Furthermore, a Glenopolar Angle (GPA) $<20^\circ$ was identified in 17.1% of surgically treated patients but in only 1.1% of patients managed conservatively ($p < 0.001$).

Among patients with glenoid fractures, 25.7% met the imaging criteria for surgical treatment based on the extent of articular involvement. In addition to accurately defining the location and extent of the articular injury, CT enabled reliable assessment of glenohumeral joint instability, thereby providing essential information for selecting the most appropriate treatment strategy.

The present study demonstrated that morphological parameters, including the Glenopolar Angle (GPA), Lateral Border Offset (LBO), scapular body angulation, and the extent of glenoid articular involvement, are important indicators for determining surgical indications. CT enables accurate measurement of these parameters, thereby reducing the risk of underestimating injury severity when assessment is based solely on conventional radiography.

Beyond its diagnostic value and role in surgical decision-making, CT also plays a pivotal role in preoperative planning. Three-dimensional (3D) reconstruction provides detailed visualization of the fracture configuration, number of fracture fragments, direction of displacement, and the relationship between the fracture and the glenoid. This information facilitates the selection of the optimal surgical approach, appropriate implant positioning, and preparation of the fixation construct. In clinical practice, CT enables surgeons to formulate an individualized operative strategy before surgery, thereby improving the accuracy of fracture reduction and internal fixation.

Overall, the findings of this study demonstrate that CT is markedly superior to conventional radiography in the evaluation of closed scapular fractures. CT not only substantially improves fracture detection but also significantly influences fracture classification, assessment of fracture displacement, and measurement of key morphological parameters that are critical for determining surgical indications and optimizing preoperative planning. These findings represent one of the principal contributions and novel aspects of the present dissertation.

3.3. Surgical Outcomes of Closed Scapular Fractures

Among the 220 patients included in the study, 35 patients (15.9%) underwent open reduction and internal fixation (ORIF) using anatomical locking plates. The mean postoperative follow-up period was 13.34 ± 5.16 months (range, 6–22 months), allowing evaluation of both mid-term and long-term clinical outcomes.

Intraoperative Outcomes

The majority of patients (88.6%) did not require perioperative blood transfusion, indicating minimal intraoperative blood loss and effective hemostatic control. Surgery was performed predominantly in the prone position (65.7%), which was most appropriate for fractures involving the scapular body and neck requiring posterior exposure, whereas the lateral decubitus position was used in 34.3% of cases.

Two surgical approaches were employed according to the fracture pattern and anatomical location: the Brodsky approach in 62.9% of patients and the modified Judet approach in 37.1%. The mean skin incision length was 11.51 ± 2.38 cm, providing adequate exposure of the fracture while minimizing soft tissue dissection. Most patients (85.7%) required only one anatomical locking plate, with a mean of 6.03 ± 2.12 screws used for fixation. Additional fixation devices, such as cerclage wire or Kirschner wires (K-

wires), were required in only 8.6% of cases, indicating that anatomical locking plates provided sufficient fixation stability in the majority of patients.

Postoperative drainage was placed in 97.1% of patients. The mean operative time was 48.71 ± 12.33 minutes, and 85.7% of procedures were completed within 60 minutes, demonstrating that the surgical technique was both efficient and reproducible. In addition to scapular fixation, 17.1% of patients underwent concomitant clavicular fixation, whereas 2.9% required fixation of the humerus or ribs because of associated injuries.

Early Postoperative Outcomes

Postoperative pain was well controlled, with a mean Visual Analog Scale (VAS) score of 3.49 ± 0.56 . Nearly half of the patients experienced mild pain ($\text{VAS} \leq 3$), while the remaining patients reported moderate pain. No cases of severe postoperative pain were recorded.

The mean postoperative hospital stay was 4.60 ± 3.02 days, and 80.0% of patients were discharged within 7 days, indicating a favorable early postoperative recovery.

According to the ASEPSIS wound scoring system, 97.1% of patients achieved uneventful wound healing without evidence of surgical site infection. Only one patient (2.9%) developed a superficial surgical site infection, and no cases of deep infection were observed.

Postoperative radiographic evaluation demonstrated anatomical or near-anatomical reduction in 100% of patients, with a residual fracture displacement ≤ 5 mm. In addition, 94.3% of patients had a residual angular deformity $\leq 10^\circ$, and all patients achieved complete or near-complete restoration of shoulder girdle alignment. The mean postoperative Glenopolar Angle (GPA) was $37.6 \pm 4.07^\circ$, which was within the normal physiological range. Among patients with glenoid fractures, 100% achieved satisfactory

glenohumeral joint congruity, and no intra-articular implant penetration was observed.

The postoperative complication rate was low, with 94.3% of patients experiencing no complications. Only one case of pneumonia and one case of superficial surgical site infection were recorded. No patients developed deep infection, implant failure, loss of reduction, or postoperative mortality.

Late Postoperative Outcomes

During follow-up, postoperative pain continued to improve progressively. The mean Visual Analog Scale (VAS) score decreased from 2.49 ± 0.82 at 3 months to 1.66 ± 0.68 at 6 months, further declining to 1.31 ± 0.47 at the final follow-up.

Fracture healing progressed uneventfully. At 3 months, 57.1% of patients achieved complete radiographic union. By 6 months and at the final follow-up, 100% of patients had achieved fracture union, with no cases of delayed union or nonunion.

Health-related quality of life improved steadily throughout the follow-up period. The mean EQ-5D-5L index increased from 0.8029 at 3 months to 0.9627 at 6 months, reaching 0.9825 at the final follow-up. Overall, 94.3% of patients achieved a good quality of life, and no patients reported poor health-related quality of life.

Shoulder range of motion recovered substantially in all planes of movement. At the final follow-up, the mean forward flexion was 170.8° , shoulder abduction reached 168.3° , external rotation averaged 65.2° , and internal rotation reached the T10–T12 vertebral level, indicating recovery to near-normal physiological shoulder motion.

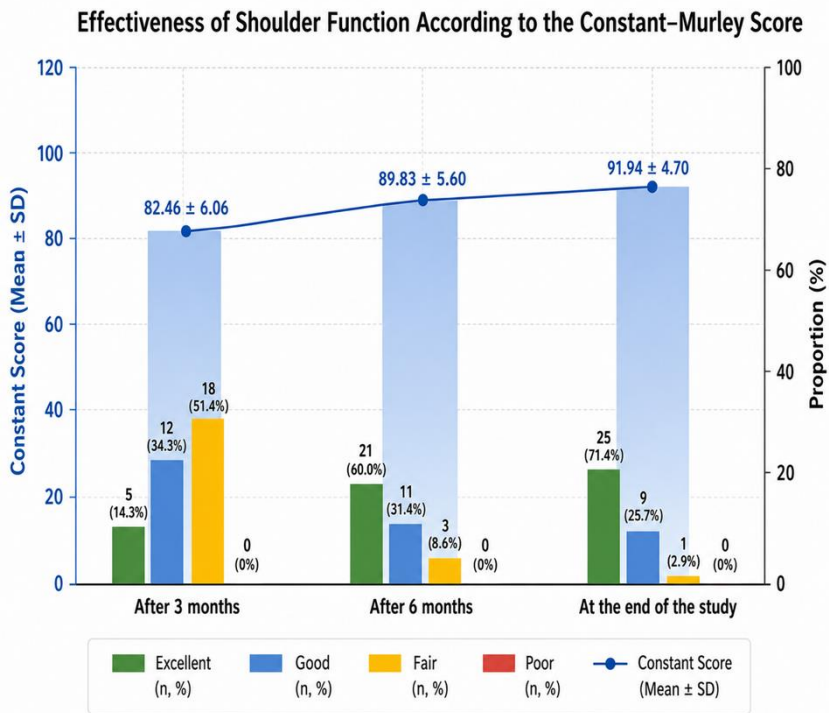


Figure 3.6. Shoulder function outcomes according to the Constant–Murley score.

Shoulder function, as assessed using the Constant–Murley Score, improved progressively throughout the follow-up period. The mean score increased from 82.46 ± 6.06 at 3 months to 89.83 ± 5.60 at 6 months, reaching 91.94 ± 4.70 at the final follow-up. The proportion of patients achieving excellent or good functional outcomes increased from 48.6% at 3 months to 97.1% at the final follow-up, with no patients demonstrating poor functional outcomes. Overall, open reduction and internal fixation (ORIF) using anatomical locking plates achieved excellent anatomical reduction, a high fracture union rate,

substantial recovery of shoulder function, and marked improvement in health-related quality of life, while maintaining a low complication rate. These findings confirm that ORIF with anatomical locking plates is an effective treatment for closed scapular fractures when appropriate surgical indications are present.

CHAPTER 4: DISCUSSION

4.1. General Characteristics of the Study Population

The present study included 220 patients with closed scapular fractures treated at two major trauma centers in Vietnam, Viet Duc University Hospital and Viet Tiep Friendship Hospital. Male patients accounted for 84.1% of the study population, with a male-to-female ratio of approximately 5.3:1, consistent with the epidemiological characteristics reported in previous studies. This predominance is likely attributable to the greater involvement of working-age men in road traffic, heavy manual labor, and other activities associated with high-energy trauma. The mean patient age was 48.94 ± 15.21 years, which is comparable to the findings reported by Schmidt, Anavian, and Vidović, indicating that scapular fractures occur predominantly in the economically active population.

Road traffic accidents were the leading mechanism of injury, accounting for 70.0% of all cases, followed by falls from height and occupational injuries. These findings are consistent with those reported by Zlowodzki, Ideberg, and Coimbra, confirming that scapular fractures are typically the result of high-energy trauma and are frequently associated with multiple injuries.

Most patients were in stable general condition at hospital admission, with the majority classified as ASA Physical Status I or II. Nevertheless, the incidence of associated injuries was high, particularly traumatic brain injury, thoracic trauma, and extremity fractures. Most patients had an Injury Severity Score (ISS) ranging from 9 to 24, reflecting the polytrauma nature of this patient population. Importantly, all patients who underwent surgical treatment had an ISS <16 , indicating that the decision to perform surgery depended not only on the characteristics of the scapular fracture but also on the patient's overall clinical condition.

The most common clinical manifestations included shoulder pain, restricted shoulder motion, localized tenderness, and soft-tissue swelling. However, these clinical findings were generally nonspecific and were frequently obscured by associated injuries in polytrauma patients, underscoring the critical role of diagnostic imaging in the accurate detection and comprehensive assessment of scapular fractures.

4.2. Imaging Characteristics of Closed Scapular Fractures

The present study demonstrated that conventional radiography detected only 70.5% of scapular fractures, whereas nearly 30% of fractures were missed and subsequently identified by computed tomography (CT). The detection rate of conventional radiography was significantly higher in the surgical group than in the non-operative group, indicating that markedly displaced fractures are more readily recognized on plain radiographs. However, fractures involving the glenoid, scapular neck, coracoid process, acromion, and scapular spine showed relatively low detection rates on conventional radiography because of the overlap of surrounding anatomical structures.

Our findings are consistent with those reported by Zlowodzki, Anavian, Armitage, and Bartoniček, all of whom emphasized the superiority of CT in the evaluation of scapular fractures. In addition to improving fracture detection, CT substantially altered the assessment of fracture fragmentation, AO/OTA classification, and the extent of articular involvement.

One of the most important findings of this study is that CT provided a more accurate evaluation of the key morphological parameters used to determine surgical indications, including the Glenopolar Angle (GPA), Lateral Border Offset (LBO), scapular body angulation, and the extent of glenoid articular involvement. Compared with conventional radiography, CT demonstrated significantly lower GPA values, greater LBO, greater angular deformity, and more extensive articular involvement. These findings indicate that

conventional radiography tends to underestimate fracture severity, whereas CT more accurately reflects the true anatomical characteristics of the injury.

The present study also demonstrated that CT accurately identified the imaging criteria commonly used to determine surgical indications, including GPA $<20^\circ$, LBO ≥ 20 mm, scapular body angulation $>40^\circ$, and glenoid articular involvement $\geq 20\%$. These parameters have been widely recommended in the international literature, and the present study provides further evidence supporting their applicability in a Vietnamese patient population.

An important practical finding of this study was the identification of patients who fulfilled the morphological criteria for surgical treatment but were managed non-operatively because of severe polytrauma and an Injury Severity Score (ISS) ≥ 16 . This observation reflects real-world clinical practice, in which treatment decisions are determined not only by CT findings but also by the patient's overall clinical condition.

Overall, the findings of this study confirm that multidetector CT with three-dimensional (3D) reconstruction is an indispensable imaging modality in the evaluation of closed scapular fractures. CT not only improves fracture detection but also provides comprehensive assessment of fracture morphology, enables accurate fracture classification, facilitates appropriate treatment selection, and serves as an essential tool for preoperative planning.

4.3. Surgical Outcomes

A total of 35 patients underwent open reduction and internal fixation (ORIF) using anatomical locking plates. The Brodsky and modified Judet approaches were selected according to the fracture pattern to provide adequate fracture exposure while minimizing soft tissue dissection. In most cases, fixation was achieved using a single anatomical locking plate positioned along the lateral border of the scapula, which is consistent with current surgical practice.

The mean operative time was 48.71 ± 12.33 minutes, which is shorter than that reported in many international studies. This favorable result may be attributed to appropriate selection of the surgical approach, meticulous preoperative planning based on three-dimensional CT reconstruction, and the experience of the operating surgeons. Intraoperative blood loss was minimal, most patients did not require blood transfusion, and no intraoperative complications were recorded, indicating that ORIF using anatomical locking plates is a safe and reliable surgical technique.

Postoperative radiographic evaluation demonstrated satisfactory anatomical reduction in all patients, with residual fracture displacement ≤ 5 mm, residual angular deformity $\leq 10^\circ$ in most cases, and restoration of glenohumeral joint congruity. Fracture union was achieved in 57.1% of patients at 3 months and in 100% by 6 months, with no cases of nonunion or fixation failure.

Shoulder function improved progressively throughout the follow-up period. The Constant–Murley Score increased steadily from 3 months to the final follow-up, and 97.1% of patients achieved excellent or good functional outcomes. Health-related quality of life, as measured by the EQ-5D-5L, also improved significantly, indicating satisfactory functional recovery and successful reintegration into daily activities following surgery.

The findings of the present study are consistent with those reported by Anavian, Bartoníček, Cole, and other investigators, demonstrating that ORIF using anatomical locking plates provides reliable anatomical restoration, a high fracture union rate, and excellent recovery of shoulder function. Furthermore, selecting patients for surgery based on CT-derived morphological parameters contributed to improved treatment outcomes and a reduced risk of postoperative complications.

4.4. Scientific Contributions and Clinical Significance of the Study

The present study provides comprehensive data on the imaging characteristics of closed scapular fractures in Vietnam based on a cohort of 220 patients, together with a longitudinal evaluation of the surgical outcomes in 35 patients treated with open reduction and internal fixation (ORIF) using anatomical locking plates.

A major novel finding of this study is the demonstration of the superior value of computed tomography (CT) in the evaluation of scapular fractures through direct comparison with conventional radiography. CT not only substantially improved fracture detection but also influenced AO/OTA fracture classification, enabled more accurate measurement of clinically relevant morphological parameters, and provided essential information for determining surgical indications.

The study also clarified the relationship between imaging-derived morphological parameters and treatment decision-making in routine clinical practice. Furthermore, it demonstrated that patients' overall clinical condition and the severity of associated injuries, particularly the Injury Severity Score (ISS), are important factors influencing the feasibility of surgical intervention. These findings provide additional scientific evidence to support the development of standardized diagnostic protocols and optimized treatment strategies for closed scapular fractures in Vietnam.

CONCLUSIONS

Based on the analysis of 220 patients with closed scapular fractures, including 35 patients treated with open reduction and internal fixation (ORIF) using anatomical locking plates at Viet Duc University Hospital and Viet Tiep Friendship Hospital between September 2023 and December 2025, the following conclusions were drawn:

1. Imaging Characteristics of Closed Scapular Fractures

- Closed scapular fractures occurred predominantly in working-age men, with road traffic accidents representing the most common mechanism of injury. Although most patients sustained multiple injuries, those who underwent surgical treatment generally had a stable general condition (ISS <16).
- Conventional radiography detected only 70.5% of scapular fractures and failed to identify nearly 30% of cases, particularly fractures involving the coracoid process, acromion, and scapular spine.
- Multidetector computed tomography (MDCT) with three-dimensional (3D) reconstruction provided more accurate assessment of fracture location, fracture fragmentation, degree of displacement, and AO/OTA fracture classification. In addition, CT enabled precise measurement of important morphological parameters, including the Glenopolar Angle (GPA), Lateral Border Offset (LBO), scapular body angulation, and the extent of glenoid articular involvement, thereby providing essential information for treatment decision-making and preoperative planning.
- Fifteen point nine percent (15.9%) of patients met the criteria for surgical treatment. Some patients fulfilled the morphological

indications for surgery but were managed non-operatively because of severe polytrauma and poor general condition.

2. Surgical Outcomes of Closed Scapular Fractures

- Open reduction and internal fixation using anatomical locking plates, performed through either the Brodsky approach or the modified Judet approach, was a safe and effective surgical procedure, with a relatively short operative time. In most patients, stable fixation was achieved using a single anatomical locking plate.
- Postoperative radiographic evaluation demonstrated anatomical or near-anatomical reduction in 100% of patients. The fracture union rate was 57.1% at 3 months and reached 100% by 6 months.
- Shoulder function and health-related quality of life improved progressively during follow-up. The mean Constant–Murley Score reached 91.94 ± 4.70 at the final follow-up, with 97.1% of patients achieving excellent or good functional outcomes. The mean EQ-5D-5L index increased to 0.9825, indicating excellent recovery of health-related quality of life.
- Open reduction and internal fixation using anatomical locking plates is an effective treatment for appropriately selected patients with closed scapular fractures, providing reliable anatomical restoration, a high fracture union rate, excellent functional recovery of the shoulder, and significant improvement in health-related quality of life.

RECOMMENDATIONS

1. Diagnostic Imaging

- Computed tomography (CT), particularly three-dimensional (3D) CT reconstruction, should be routinely performed in patients with suspected scapular fractures or when conventional radiography does not adequately characterize the injury. This approach may reduce the risk of missed diagnoses and enable accurate assessment of fracture displacement, fracture fragmentation, and glenoid involvement.
- Treatment decisions should not be based solely on conventional radiography, as plain radiographs may underestimate the severity and complexity of scapular fractures.

2. Treatment Indications

- Early surgical intervention should be considered for patients presenting with marked fracture displacement, reduced Glenopolar Angle (GPA), comminuted fractures (≥ 3 fragments), or glenoid articular surface involvement exceeding 20%.
- Comprehensive assessment of the patient's general condition and associated injuries, particularly thoracic injuries, should be performed before deciding on surgical intervention.