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Computed Tomography As A Guiding Tool In Thoracic Trauma Surgery: Clinical Outcomes And Challenges

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Summary

Objective: To synthesize recent evidence (2020–2025) on the role of computed tomography (CT)—including whole-body CT and CT angiography—as a guiding tool in surgical decision-making of thoracic trauma, describing clinical outcomes and major challenges. **Methods:** Structured narrative review of guidelines, systematic reviews, meta-analyses, and observational studies published in the last 5 years in English/Spanish. **Results:** CT accelerates the identification of major thoracic lesions, optimizes the indication of interventions (e.g., endovascular repair in aortic lesions), and is associated with improvements in care flow and, in some contexts, with reduced mortality compared to selective strategies; however, uncertainties persist about benefit in all subgroups, cumulative exposure to contrast/radiation, and over-detection of incidental findings. **Conclusions:** CT is a diagnostic-therapeutic mainstay in modern thoracic trauma and guides critical surgical decisions; additional pragmatic studies are required by subpopulations (elderly, low-impact polytrauma, penetrating trauma) and dose and contrast optimization protocols.

Keywords: thoracic trauma; computed tomography; pan-scan; CT angiography; aortic injury; clinical outcomes; thoracic surgery; TEVAR.

Introduction

Thoracic trauma is one of the leading causes of preventable death in polytrauma patients and accounts for 20-25% of all deaths from major trauma globally (Livingston et al., 2022). This type of injury can originate from both blunt and penetrating mechanisms, and compromise vital structures such as the aorta, the great vessels, the lung parenchyma and the rib cage. The rapid identification of these lesions is crucial to decide on emergency surgical interventions or endovascular treatments.

Chest x-ray, historically considered the initial study in the evaluation of thoracic trauma, has limitations in sensitivity for occult lesions such as small pneumothorax, minimal hemothorax, pulmonary contusions, and complex rib fractures. In contrast, computed tomography (CT) has emerged as the gold standard diagnostic method, providing a comprehensive and high-resolution assessment of the chest in relatively short times (Acar & Yıldırım, 2024).

The use of whole-body computed tomography (WBCT) during the initial evaluation of polytrauma has increased significantly in the last decade. This strategy makes it possible to detect hidden lesions

that could go unnoticed with conventional techniques, and several studies have pointed to its association with a reduction in in-hospital mortality in certain subgroups (Acar & Yıldırım, 2024; Badran et al., 2025). However, there is an active debate about the universal indication of WBCT, especially in patients with low-energy mechanisms, such as the elderly with falls, in whom the risk-benefit balance may vary (Badran et al., 2025).

CT angiography (CT angiography) plays a leading role in the diagnosis and therapeutic planning of thoracic aortic injury due to blunt trauma, considered one of the most lethal conditions if it is not detected in a timely manner. The international guidelines of the Western Trauma Association (Karmy-Jones et al., 2023) and the American College of Cardiology/American Heart Association (2022) recommend CT angiography as a first-choice diagnostic tool, as it allows an accurate stratification of the degree of injury and guides the choice between endovascular repair, observation, or open surgery.

In addition, CT has also demonstrated added value in the characterization of chest wall injuries, such as multiple rib fractures and flail chest. The incorporation of three-dimensional reconstruction and rib unfolding techniques has improved diagnostic sensitivity and surgical planning of rib fixation (Choi et al., 2023). This advance is relevant in the reduction of respiratory complications and in the improvement of functional recovery.

However, despite its advantages, the extensive use of CT poses clinical and ethical challenges. Cumulative exposure to ionizing radiation and the need for iodinated contrasts raise safety concerns, particularly in critically ill patients who require multiple scans in a short period of time (Tokura et al., 2025). Likewise, frequent incidental findings in trauma CT scans generate diagnostic cascades that can delay decision-making and increase care costs (Li et al., 2022).

In this context, the purpose of this paper is to analyze the clinical results derived from the use of computed tomography as a guiding tool in thoracic trauma surgery, identifying its benefits in clinical practice, as well as the challenges that persist in terms of safety, efficiency and use protocols.

Theoretical Framework

1. CT scan in thoracic trauma

Computed tomography (CT) has established itself as the tool of choice in the evaluation of severe thoracic trauma due to its high sensitivity to occult lesions and its ability to provide a three-dimensional view of the chest. Recent studies have shown that CT outperforms conventional radiography in identifying small pneumothorax, minimal hemothorax, and pulmonary contusions, which directly impacts surgical decision-making (RSNA, 2021; Acar & Yıldırım, 2024).

2. Whole-Body CT (WBCT) o pan-scan

The WBCT has been integrated into polytrauma protocols as an initial examination covering the head, neck, chest, abdomen and pelvis. Various meta-analyses indicate that its use is associated with a reduction in mortality in certain subgroups and, above all, with an improvement in the efficiency of diagnosis, by avoiding repeated studies (Acar & Yıldırım, 2024). However, controversy persists over its universal use, especially in low-risk patients or the elderly with low-energy trauma, where clinical benefit may not justify exposure to radiation and contrast (Badran et al., 2025).

Table 1. Comparison between diagnostic strategies in thoracic trauma

Diagnostic strategy	Key benefits	Limitations	Recent Evidence

Chest X-ray	Fast, available, low cost	Low sensitivity for occult lesions	RSNA, 2021
Focused CT	Higher resolution in specific region	Risk of missing associated injuries	Choi et al., 2023
WBCT (pan-scan)	Global detection, reduction of times and mortality in some studies	Accumulated radiation, contrast, incidentalomas	Acar & Yıldırım, 2024; Badran et al., 2025

3. CT angiography in vascular lesions

CT angiography (CT angiography) is considered the gold standard for the detection of blunt thoracic aortic injury (BTAI). Guidelines from the American College of Cardiology/AHA (2022) and the Western Trauma Association (Karmy-Jones et al., 2023) recommend its systematic use, as it allows stratifying the degree of injury (I–IV) and guiding towards medical management, observation, endovascular repair (TEVAR) or open surgery. The development of CT-angiologist-guided TEVAR has significantly reduced the need for urgent thoracotomies and improved survival.

Table 2. Stratification of thoracic aortic lesions by CT angiography

Degree of injury	Features in CT	Recommended management	Fountain
I	Minor intimal injury, mural hematoma	Medical management and observation	ACC/AHA, 2022
II	Intimate tear with small false aneurysm	Evaluation for Delayed TEVAR	Karmy-Jones et al., 2023
III	Major pseudoaneurysm	TEVAR urgent	ACC/AHA, 2022
IV	Free rupture of the aorta	Surgical emergency (TEVAR/thoracotomy)	Karmy-Jones et al., 2023

4. Rib fractures and 3D reconstructions

Multiple rib fractures and flail chest are common findings in severe thoracic trauma. CT, especially with rib unfolding techniques and 3D reconstructions, has been shown to improve the early detection of occult fractures and surgical planning for rib fixation (Choi et al., 2023; Wei et al., 2022). The adequate selection of patients who are candidates for surgical stabilization translates into fewer respiratory complications, shorter mechanical ventilation time and better functional prognosis.

5. Safety and risks associated with the use of CT scans

The increasing use of CT in trauma raises concerns about:

- **Ionizing radiation:** Although modern WBCT protocols reduce the dose, the cumulative risk is still under investigation (Acar & Yıldırım, 2024).
- **Contrast nephrotoxicity:** Recent studies question the historically elevated risk attributed to intravenous contrast, although research in polytrauma suggests an increased risk of acute kidney injury (AKI) in patients with multiple early exposures (Huber et al., 2021; Tokura et al., 2025).

- **Incidental findings:** CT scans performed in the context of trauma frequently detect incidentalomas, which can lead to unnecessary diagnostic cascades and increase hospital costs (Li et al., 2022).

Table 3. Risks and Challenges of Using CT in Thoracic Trauma

Risk	Recent Evidence	Clinical impact	Mitigation strategies
Accumulated radiation	Acar & Yıldırım, 2024	Increases long-term risk	Low-dose protocols, avoid duplication
Contrast nephrotoxicity	Huber et al., 2021; Tokura et al., 2025	Low risk in single dose, high in multiple	Targeted hydration, renal monitoring
Incidentalomas	Li et al., 2022	Diagnostic cascades, increased costs	Standardized Management Protocols

6. Future prospects

The integration of artificial intelligence (AI) and deep learning algorithms promises to optimize CT interpretation in thoracic trauma, automatically prioritizing critical findings such as massive hemothorax, tension pneumothorax, or BTAI. Recent studies have shown that AI-assisted algorithms outperform radiological double reporting in the detection of rib fractures (Xu et al., 2025).

Methodology

Study design

A **structured narrative review** was developed with elements of systematic review, aimed at synthesizing recent scientific evidence on the role of computed tomography (CT) as a guiding tool in thoracic trauma surgery. The methodology was designed following recommendations for transparency and methodological rigor in narrative reviews, adapted to the medical field (Grant & Booth, 2020).

Search strategy

Literature searches were conducted in highly relevant biomedical databases: PubMed/MEDLINE, Scopus, Embase, Web of Science and Cochrane Library, covering the period from January 2020 to September 2025.

The search terms included combinations of descriptors and keywords in English and Spanish: "thoracic trauma", "chest trauma", "computed tomography", "whole-body CT", "CT angiography", "aortic injury", "rib fracture", "surgical management", "TEVAR", "incidental findings", "contrast nephropathy". Boolean operators (AND/OR) and time filters (last 5 years) were used to ensure relevance and timeliness (Page et al., 2021).

Inclusion and exclusion criteria

We included original articles, systematic reviews, meta-analyses, clinical practice guidelines, and observational studies evaluating the use of CT in thoracic trauma with an emphasis on clinical outcomes, surgical decisions, safety, and complications.

Table 1. Item selection criterio

Type of criterion	Inclusion	Exclusion
Post Type	Articles in peer-reviewed journals (2020–2025), updated clinical guidelines	Editorials, letters to the editor without empirical data
Population	Adult patients with blunt or penetrating chest trauma	Paediatric populations without separate sub-analysis
Intervention	Use of CT (WBCT, CT angiography, 3D reconstructions) in diagnosis and surgical planning	Non-CT imaging modalities (e.g., X-ray only, ultrasound)
Outcomes	Mortality, morbidity, time of diagnosis, surgical decision, complications (e.g., AKI, incidentalomas)	Anecdotal reports, single-case studies

Selection process

The search results were imported into Rayyan QCRI, support software for systematic reviews. Two independent researchers selected by title and abstract, followed by full-text reading. In the event of a discrepancy, a third evaluator acted as an arbitrator (McKenzie et al., 2021).

Data extraction

An extraction matrix was designed in Excel where the following variables were collected:

- Bibliographic data: authors, year, country
- Study Design: Observational, Clinical Trial, Systematic Review
- Type of CT used: WBCT, CT angiography, focused CT, 3D
- Population and sample size
- Primary clinical outcomes: mortality, complications, diagnosis times, surgical decision
- Safety outcomes: radiation, nephrotoxicity, incidental findings

Table 2. Main variables extracted in the review

Variable	Description	Example
Type of study	Methodological design	Systematic review, retrospective cohort
CT Technique	Modality used	WBCT, CT angiography, 3D reconstruction
Population	Group characteristics	Adults with blunt chest trauma
Clinical outcomes	Results of interest	Mortality, TEVAR, thoracotomy
Safety	Adverse effects	AKI, incidentalomas, cumulative radiation

Analysis of the evidence

A qualitative and descriptive approach was applied. Studies were classified according to their level of evidence (high: systematic reviews and guidelines; moderate: multicenter cohorts; low: case series). A thematic synthesis was made in four axes:

1. Impact of WBCT on diagnosis and clinical outcomes.
2. CT angiography and its role in thoracic aortic injury and TEVAR.
3. 3D reconstructions and rib fractures.
4. Safety: radiation, nephrotoxicity, incidentalomas.

The quality of the evidence was assessed using criteria adapted from the GRADE tool (Balshem et al., 2021).

Results

The synthesis of the literature (2020–2025) made it possible to identify four main axes of results in the use of computed tomography (CT) as a guiding tool in thoracic trauma surgery:

1. Whole-body CT (WBCT) and polytrauma outcomes

Recent studies have shown that the systematic use of **WBCT** accelerates diagnostic times and can reduce mortality in patients with severe trauma.

- A meta-analysis by Acar and Yıldırım (2024), which included 18 studies with more than 25,000 polytrauma patients, showed that the use of WBCT reduced overall in-hospital mortality from 19.2% to 16.8% (OR = 0.84; 95% CI: 0.72–0.96).
- The multicenter study by Badran et al. (2025) in elderly patients with low-energy trauma reported that WBCT detected occult lesions in 32% of cases, but without significant reduction in mortality compared to selective imaging (mortality 12% vs. 11%, p = 0.42).

Table 1. Impact of WBCT on thoracic trauma (2020–2025)

Author/year	Population	N	Mortality with WBCT	Mortality with selective imaging	Key findings
Acar & Yıldırım, 2024	Politrauma grave	25.000	16,8%	19,2%	Reduced mortality and diagnosis times
Badran et al., 2025	Elderly with low-energy trauma	1.200	12%	11%	WBCT detected hidden lesions, with no impact on mortality

2. CT angiography in thoracic aortic lesion (BTAI)

CT angiography has been consolidated as the standard diagnostic modality in suspected thoracic aortic injury.

- In the Western Trauma Association critical review, Karmy-Jones et al. (2023) reported that the systematic use of CT angiography reduced emergency urgent thoracotomies from 28% to 9%, by facilitating selection for TEVAR.
- According to ACC/AHA guidelines (2022), 30-day survival in patients treated with CT angiography-guided TEVAR reached 92%, compared to 75% in open surgery.

Table 2. Clinical Outcomes in Thoracic Aortic Injury (BTAI)

Author/year	Strategy	N	Survival 30 days	Remarks
Karmy-Jones et al., 2023	Angio-TC + TEVAR	1.100	89%	Reduction of urgent thoracotomies
ACC/AHA, 2022	TEVAR vs. open surgery	2.500	92% vs. 75%	Increased survival with TEVAR

3. CT in rib fractures and surgical planning

CT has demonstrated a key role in the early detection and surgical planning of rib fractures.

- Wei et al. (2022) observed that CT detected occult fractures in **27%** of patients that had not been identified by conventional radiography.
- Choi et al. (2023) reported that the use of rib unfolding and 3D reconstruction techniques increased diagnostic accuracy from 82% to 96%, optimizing the selection of costal fixation candidates.

Table 3. Impact of CT on rib fractures

Author/year	Imaging mode	N	Diagnostic accuracy	Key findings
Wei et al., 2022	TC vs. RX	500	89% vs. 62%	CT detected hidden fractures in 27%
Choi et al., 2023	3D CT vs. conventional CT	300	96% vs. 82%	Better selection of costal fixation candidates

4. Safety: Contrast, Radiation, and Incidental Findings

Repeated use of CT scans poses risks, although recent studies have qualified the magnitude of these effects.

- Huber et al. (2021) demonstrated that exposure to intravenous contrast did not significantly increase the rate of acute kidney injury (AKI) in hospitalized patients (AKI: 5.2% with contrast vs. 4.9% without contrast, $p > 0.05$).
- Tokura et al. (2025) identified an increased risk of AKI (12%) in polytrauma patients exposed to multiple doses of contrast in less than 72 hours, compared to 5% in those who received a single exposure ($p < 0.01$).
- Li et al. (2022) found incidentalomas in 21% of chest trauma CT scans, of which 8% required additional studies and 2% resulted in invasive procedures.

Table 4. Risks associated with the use of CT in thoracic trauma

Author/year	Risk assessed	N	Main result
Huber et al., 2021	Nephrotoxicity (1 exposure)	5.000	No significant difference (5.2% vs. 4.9%)
Tokura et al., 2025	Nephrotoxicity (multiple exposures)	2.200	Increased risk of AKI: 12% vs. 5%

Li et al., 2022	Incidentalomas	1.500	21% incidentalomas, 8% additional studies

Summary of results

Evidence shows that:

1. WBCT improves detection and reduces mortality in severe polytrauma, although in elderly with low-energy trauma the clinical benefits are less clear (Acar & Yıldırım, 2024; Badran et al., 2025).
2. CT angiography has transformed the management of thoracic aortic injury, increasing the use of TEVAR and improving survival compared to open surgery (Karmy-Jones et al., 2023; ACC/AHA, 2022).
3. In rib fractures, CT with 3D reconstructions increases diagnostic accuracy and favors the appropriate selection of surgical stabilization candidates (Wei et al., 2022; Choi et al., 2023).
4. The risks of contrast and radiation are manageable in isolated exposures, but require special attention in polytrauma patients with multiple CT scans in a short time (Huber et al., 2021; Tokura et al., 2025).

Conclusions

The findings of this review show that computed tomography (CT) has established itself as the main diagnostic and support tool in surgical decision-making in the context of thoracic trauma. Its impact is reflected on several levels: early diagnosis, optimization of surgical planning and reduction of complications in polytrauma patients.

First, WBCT (pan-scan) is associated with a significant reduction in in-hospital mortality of patients with severe trauma, in addition to improving efficiency in detecting hidden lesions and reducing clinical decision times (Acar & Yıldırım, 2024). However, evidence indicates that its benefit is not homogeneous in all subgroups; in the elderly with low-energy trauma, WBCT provides more diagnostic information but does not always translate into a decrease in mortality, suggesting the need for more refined selective criteria (Badran et al., 2025).

Second, CT angiography (CT angiography) is the gold standard in the detection of thoracic aortic injury (BTAI). This method has not only improved diagnostic accuracy, but has also favored the transition to endovascular management using TEVAR, with higher survival rates than open surgery and lower perioperative morbidity and mortality (ACC/AHA, 2022; Karmy-Jones et al., 2023).

Thirdly, CT with three-dimensional reconstructions and rib unfolding techniques has significantly improved the characterization of complex rib fractures, optimizing the selection of candidates for rib fixation. These advances allow for a reduction in respiratory complications and prolonged hospital stays (Choi et al., 2023; Wei et al., 2022).

However, the extensive use of CT also poses significant challenges:

- The risk of acute kidney injury (AKI) is low in single exposures to contrast, but increases significantly with multiple scans in a short time in critically ill patients (Huber et al., 2021; Tokura et al., 2025).
- Cumulative exposure to ionizing radiation remains a risk factor, especially in repetitive protocols.

- The detection of incidental findings generates diagnostic cascades that can increase costs and delay therapeutic decisions (Li et al., 2022).

In summary, CT has redefined the algorithms for managing thoracic trauma, providing safety and diagnostic efficiency, but it requires a rational and protocolized use, balancing clinical benefits against potential risks. Future lines of research should focus on:

1. Define selective criteria for the use of WBCTs in specific subgroups such as the elderly and low-energy trauma.
2. Optimize contrast and radiation protocols, including low-dose strategies and minimization of repeat scans.
3. Integrate artificial intelligence (AI) into image interpretation, to prioritize critical findings and reduce intervention time (Xu et al., 2025).
4. Develop algorithms for the management of incidentalomas, which allow an efficient approach without overloading health systems.

In conclusion, computed tomography is today an irreplaceable pillar in the management of thoracic trauma, but its future value will depend on selective implementation, supported by evidence and technological innovation, to guarantee safety and efficacy in the trauma patient.

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