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REVIEW ARTICLE

# Surgical management of chest injuries in patients with multiple and/or severe trauma– a systematic review and clinical practice guideline update

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## Abstract

**Purpose** Our aim was to update evidence-based and consensus-based recommendations for the surgical and interventional management of blunt or penetrating injuries to the chest in patients with multiple and/or severe injuries on the basis of current evidence. This guideline topic is part of the 2022 update of the German Guideline on the Treatment of Patients with Multiple and/or Severe Injuries.

**Methods** MEDLINE and Embase were systematically searched to May and June 2021 respectively for the update and new questions. Further literature reports were obtained from clinical experts. Randomised controlled trials, prospective cohort studies, cross-sectional studies and comparative registry studies were included if they compared interventions for the surgical management of injuries to the chest in patients with multiple and/or severe injuries. We considered patient-relevant clinical outcomes such as mortality, length of stay, and diagnostic test accuracy. Risk of bias was assessed using NICE 2012 checklists. The evidence was synthesised narratively, and expert consensus was used to develop recommendations and determine their strength.

**Results** One study was identified. This study compared wedge resection, lobectomy and pneumonectomy in the management of patients with severe chest trauma that required some form of lung resection. Based on the updated evidence and expert consensus, one recommendation was modified and two additional good practice points were developed. All achieved strong consensus. The recommendation on the amount of blood loss that is used as an indication for surgical intervention in patients with chest injuries was modified to reflect new findings in trauma care and patient stabilisation. The new good clinical practice points (GPPs) on the use of video-assisted thoracoscopic surgery (VATS) in patients with initial circulatory stability are also in line with current practice in patient care.

**Conclusion** As has been shown in recent decades, the treatment of chest trauma has become less and less invasive for the patient as diagnostic and technical possibilities have expanded. Examples include interventional stenting of aortic injuries, video-assisted thoracoscopy and parenchyma-sparing treatment of lung injuries. These less invasive treatment concepts reduce morbidity and mortality in the primary surgical phase following a chest trauma.

**Keywords** Surgical management · Chest · VATS in thoracic trauma · Lung injury · Tracheobronchial injury · Thoracic aortic rupture · Polytrauma guideline

## Introduction

In Germany, almost half of all polytrauma patients (46.1%) [1] present with severe thoracic trauma. A relevant thoracic trauma can immediately or at a later stage lead to a serious life-threatening condition in the presence of airway injuries (A problem) or to respiratory (B problem) and haemodynamic (C problem) compromise. In German-speaking countries, emergency thoracotomy (within one hour of arrival at the hospital) is necessary in only 0.9% of patients with an

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Injury Severity Score (ISS) ≥ 9 [2]. Due to improved stabilization measures, interventional and minimally invasive procedures that are gentle on the patient are increasingly being used in the treatment of polytrauma in patients with stable or stabilised vital signs, even when they present with thoracic injuries. The objective of this systematic review is to assess the evidence for current therapeutic and surgical procedures in the initial surgical management of thoracic trauma in the hospital setting.

## Methods

This guideline topic is part of the 2022 update of the German Guideline on the Treatment of Patients with Multiple and/or Severe Injuries [3]. The guideline update is reported according to the RIGHT tool [4], the systematic review part according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 reporting guideline [5]. The development and updating of recommendations followed the standard methodology set out in the guideline development handbook issued by the German Association of the Scientific Medical Societies (AWMF) [6]. All methods were defined a priori, following the methods report of the previous guideline version from July 2016 [7] with minor modifications, as detailed below. The Introduction and Discussion sections of this publication are summaries of the original guideline text [3].

**Table 1** Predefined selection criteria

| | |
|---|---|
| Population: | Adult patients (≥ 14 years) with polytrauma and/or severe injuries[a] |
| **Intervention /comparison**: | surgical management of injuries to the chest |
| **Outcomes**: | any patient-relevant outcome such as mortality or length of stay, diagnostic test accuracy |
| **Study type**: | • comparative, prospective studies (randomised controlled trials, cohort studies)<br>• comparative registry[b] data (incl. case-control studies)<br>• cross-sectional studies (only diagnostic studies)<br>• systematic reviews based on the above primary study types |
| **Language**: | English or German |
| **Other inclusion criteria**: | • full text of study published and accessible<br>• study matches predefined PICO question |
| **Exclusion criteria**: | • multiple publications of the same study without additional information |

[a] Defined by an Injury Severity Score (ISS) > 15, Glasgow Coma Scale (GCS) < 9, or comparable values on other scales, or, in the prehospital setting, clinical suspicion of polytrauma/severe injury with a need for life-saving interventions

[b] Using the Agency for Healthcare Research and Quality (AHRQ) definition of registries [8]

### PICO questions and eligibility criteria

Population, intervention, comparison, and outcome (PICO) questions were retained from the previous guideline version. In addition, the participating professional societies involved in guideline development were asked to submit new PICO questions. The overarching PICO question for this topic area was:

*In adult patients (≥ 14 years) with known or suspected polytrauma and/or severe injuries, does a specific surgical approach to the management of chest injuries improve patient relevant outcomes compared to any other intervention?*

The full set of predefined PICO questions is listed in Table S1 (Online Resource 1). The study selection criteria in the PICO format are shown in Table 1.

### Literature search

An information specialist systematically searched for literature in MEDLINE (Ovid) and Embase (Elsevier). The search strategy described in the 2011 Guideline was used with modifications. It contained index (MeSH/Emtree) and free text terms for the population and intervention. All searches were conducted in May and June 2021 for the update and new questions. The start date for update searches was 8 June 2014. No start date was used in the searches for new PICO questions. Table S2 (Online Resource 1) provides details for all searches. Searches were conducted for both prehospital and inhospital care. Clinical experts were asked to submit additional relevant references.

### Study selection

Study selection was performed independently by two reviewers in a two-step process using the predefined eligibility criteria: (1) title/abstract screening of all references retrieved from database searches using Rayyan software [9] and (2) full-text screening of all articles deemed potentially relevant by at least one reviewer at the title/abstract level in Endnote (Endnote, Version: 20 [Software], Clarivate, Boston, Massachusetts, USA. https://endnote.com/). Disagreements were resolved through consensus or by consulting a third reviewer. The reasons for full-text exclusion were recorded (Table S3, Online Resource 1).

### Assessment of risk of bias and level of evidence

Two reviewers sequentially assessed the risk of bias of included studies at study level using the relevant checklists from the NICE guidelines manual 2012 [10] and assigned each study an initial level of evidence (LoE) using the

Oxford Centre for Evidence-based Medicine Levels of Evidence (2009) [11]. Any disagreements were resolved through consensus or by consulting a third reviewer.

## Data extraction and data items

Data were extracted into a standardised data table by one reviewer and checked by another. A predefined data set was collected for each study, consisting of study characteristics (study type, aims, setting), patient selection criteria and baseline characteristics (age, gender, injury scores, other relevant variables), intervention and control group treatments (including important co-interventions, index and reference tests for diagnostic studies), patient flow (number of patients included and analysed), matching/adjusting variables, and data on outcomes for any time point reported.

## Outcome measures

Outcomes were extracted as reported in the study publications. For prospective cohort studies and registry data, preference was given to data obtained after propensity-score matching or statistical adjustment for risk-modulating variables over unadjusted data.

## Synthesis of studies

Studies were grouped by interventions. An interdisciplinary expert group used their clinical experience to synthesise studies narratively by balancing beneficial and adverse effects extracted from the available evidence. Priority was given to diagnostic test accuracy, reducing mortality, immediate complications, and long-term adverse effects. Clinical heterogeneity was explored by comparing inclusion criteria and patient characteristics at baseline as well as clinical differences in the interventions and co-interventions.

**Table 2** Grading of recommendations

| Symbol | Grade of recommendation | Description | Wording (examples) |
|---|---|---|---|
| ⇑⇑ | A | strong recommendation | "use…", "do not use…" |
| ⇑ | B | recommendation | "should use…", "should not use…" |
| ⇔ | 0 | open recommendation | "consider using…", "… can be considered" |

## Development and updating of recommendations

For each PICO question, the following updating options were available: (1) the recommendation of the preceding version remains valid and requires no changes ("confirmed"); (2) the recommendation requires modification ("modified"); (3) the recommendation is no longer valid or required and is deleted; (4) a new recommendation needs to be developed ("new"). An interdisciplinary expert group of clinicians with expertise in thoracic surgery, cardiac surgery, trauma surgery, and acute care reviewed the body of evidence, drafted recommendations based on the homogeneity of clinical characteristics and outcomes, the balance between benefits and harms as well as their clinical expertise, and proposed grades of recommendation (Table 2). In the absence of eligible evidence, good practice recommendations were made based on clinical experience, data from studies with a lower level of evidence, and expert consensus in cases where the Guideline Group felt a statement was required due to the importance of the topic. These were not graded, and instead labelled as good (clinical) practice points (GPP). For GPPs, the strength of a recommendation is presented in the wording shown in Table 2.

## Consensus process

The Guideline Group finalised the recommendations during a web-based, structured consensus conference on 13 September 2021 via Zoom (Zoom, Version: 5.x [Software], Zoom Video Communications, Inc., San José, California, USA. https://zoom.us). A neutral moderator facilitated the consensus conference. Voting members of the Guideline Group were delegates of all participating professional organisations, including clinicians, emergency medical services personnel and nurses, while guideline methodologists attended in a supporting role. Members with a moderate, thematically relevant conflict of interest abstained from voting on recommendations, members with a high, relevant conflict of interest were not permitted to vote or participate in the discussion. Attempts to recruit patient representatives were unsuccessful. A member of the expert group presented recommendations. Following discussion, the Guideline Group refined the wording of the recommendations and modified the grade of recommendation as needed. Agreement with both the wording and the grade of recommendation was assessed by anonymous online voting using the survey function of Zoom. Abstentions were subtracted from the denominator of the agreement rate. Consensus strength was classified as shown in Table 3.

Recommendations were accepted if they reached consensus or strong consensus. For consensus recommendations with $\leq 95\%$ agreement, diverging views by members of

**Table 3** Classification of consensus strength

| Description | Agreement rate |
|---|---|
| strong consensus | > 95% of participants |
| consensus | > 75 to 95% of participants |
| majority approval | > 50 to 75% of participants |
| no approval | < 50% of participants |

the Guideline Group were detailed in the background texts. Recommendations with majority approval were returned to the expert group for revision and further discussion at a subsequent consensus conference. Recommendations without approval were considered rejected.

### External review

During a four-week consultation phase, the recommendations and background texts were submitted to all participating professional organisations for review. Comments were collected using a structured review form. The results were then assessed, discussed and incorporated into the text by the guideline coordinator with the relevant author group.

The guideline was adopted by the executive board of the German Trauma Society on 17 January 2023.

### Quality assurance

The guideline recommendations were reviewed for consistency between guideline topic areas by the steering group. Where necessary, changes were made in collaboration with the clinical leads for all topic areas concerned. The final guideline document was checked for errors by the guideline chair and methodologist.

## Results

The database searches identified 4419 unique records (Fig. 1). Ten additional records were obtained from clinical experts, adding to the body of evidence of 22 studies previously included in the guideline [12–33]. One study was eligible for this update [34]. A total of 72 full-text articles were excluded (Table S3, Online Resource 1).

### Characteristics of studies included in this update

Study characteristics, main outcomes, levels of evidence, and risk-of-bias assessments are presented in Table 4. Full details are provided in Table S4, Online Resource 1. The evidence included one comparative registry study [34]. Eligible patient populations were adults with chest trauma (defined as AIS ≥ 3) who required some form of lung resection.

## Discussion

### Rationale for recommendations

The text below the recommendations discusses the various injuries and the surgical approach or surgical / interventional procedure. The therapeutic procedure and the surgical approach generally depend on the stability of the patient.

Surgical approach and indications for thoracotomy/thoracoscopy.

Depending on the localization of the injury, an anterolateral thoracotomy or a sternotomy can be chosen as the thoracic approach. If the location of injury is unclear, a clam shell incision can be considered. (GoR 0)

Video-assisted thoracoscopic surgery (VATS) can be used to gain thoracic access or to perform a surgical procedure in patients with cardiorespiratory stability. (GPP)

Depending on the type of trauma and the location of injury, there are different surgical approaches to emergency thoracotomy. Anterolateral thoracotomy on the injured side is the standard approach to emergency thoracotomy. When this approach is used, exposure is insufficient in approximately 20% of cases [35]. If the injury can be accurately localised before surgery, other approaches are recommended as well. A sternotomy is used for injuries to the aortic arch, the great vessels, the heart, and the ascending aorta, and a right (posterolateral) thoracotomy for injuries to the intrathoracic trachea. A supraclavicular approach with division of the clavicle provides exposure of the subclavian vessels [35–40]. Injuries to the posterior wall of the heart are better approached through an anterolateral thoracotomy.

Whereas video-assisted thoracoscopic surgery (VATS) is an unsuitable approach in patients with cardiorespiratory instability, it is increasingly preferred over the aforementioned open approaches in stable or stabilised patients. VATS allows injuries to the lung and diaphragm and other intrathoracic sources of bleeding to be safely identified and managed. It is regularly utilised for the evacuation of retained haemothoraces, usually in the post-acute setting [41–43]. VATS can also be used during thoracotomy as a hybrid procedure to explore areas that are difficult to visualise.

Thoracotomy can be performed in stable and unstable patients with initially high blood loss or ongoing relevant blood loss through a chest tube. (GPP)

Video-assisted thoracoscopic surgery (VATS) can be performed as an alternative to thoracotomy in patients with cardiopulmonary stability. (GPP)

For many decades, an initial chest tube output of > 1500 mL or a continued loss of 250 mL/hour for over four hours has been recommended as an indication for emergency thoracotomy in the acute management of chest trauma. This recommendation is based on a study that McNamara et al.

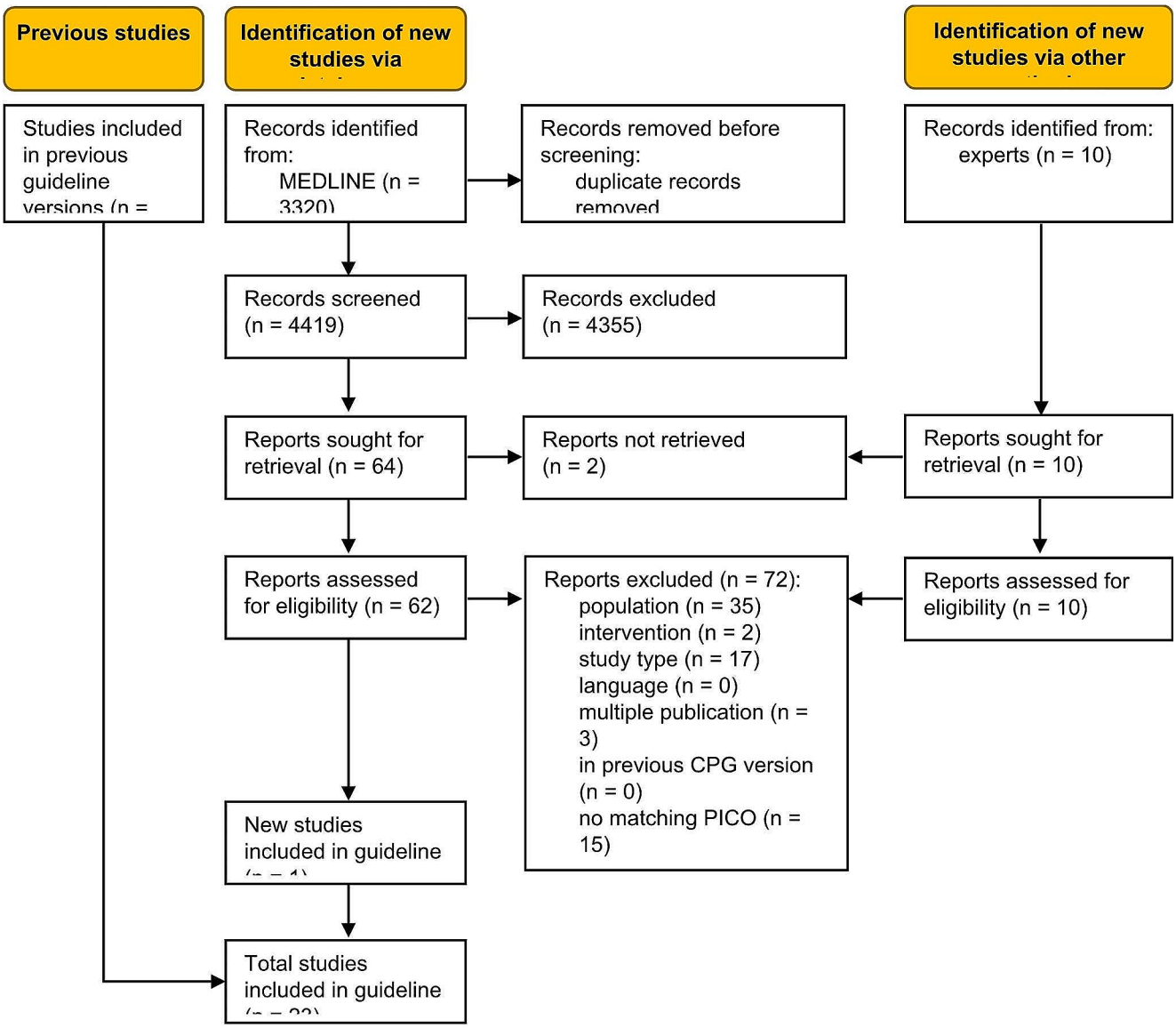


**Fig. 1** Modified PRISMA 2020 flow diagram showing the systematic literature search and selection of studies

**Table 4** Characteristics of studies included in the update (see Table S4, Online Resource 1 for further details)

| Study, reference | Design | Setting | Population | Age, ISS* | Interventions (*N* patients) | Main outcomes (selection)* | LoE, risk of bias (RoB)§ |
|---|---|---|---|---|---|---|---|
| *Parenchyma-sparing surgery for lung injuries* | | | | | | | |
| Aiolfi 2020 [34] | Comparative registry study (National Trauma Data Bank) | 2007–2015 | Patients who sustained severe chest trauma | *Age [y], mean ± SD* 33 ± 16 *Mean ISS ± SD* 25 ± 13 | *N* = 3107 IG: wedge resection (*N* = 1696) IG2: lobectomy (*N* = 1187) CG: pneumonectomy (*N* = 224) | *Overall mortality n (%)* IG: 344 (20.3) vs. IG2: 366 (30.8) vs. CG: 142 (63.4), $p < 0.001$ | LoE 2b unclear RoB |

* Data for IG versus CG unless otherwise specified. § Risk of bias: low RoB = RoB low for all domains; unclear RoB = RoB unclear for at least one domain, no high RoB in any domain; for studies with high RoB, all domains with high RoB are named, with RoB low or unclear for all other domains (for full details Table S4, Online Resource 1)

published fifty years ago on the basis of lessons learned during the Vietnam conflict and other studies that have continued the recommendations of McNamara et al. and which were published twenty or thirty years ago [40, 44–46].

For this reason, the Guideline Group addressed the question of whether this recommendation still holds since the underlying figures were reported in studies with a low level of evidence. In recent decades, stabilisation measures as well as diagnostic and therapeutic options in the management of polytrauma patients have been considerably improved so that the quantity details that provided the basis for the recommendation on indications for thoracotomy were deleted and replaced by "initially high blood loss or ongoing relevant blood loss". This modification allows patients who are stable or have been stabilised and show an initially high chest tube output, which can stop spontaneously, or ongoing blood loss to be managed in a far more differentiated manner. Diagnostic computed tomography (CT), therapeutic measures (if necessary), VATS, etc. can thus be performed.

Since 1990, VATS has been increasingly used in clinical practice as an alternative to thoracotomy in haemodynamically stable or stabilised trauma patients. Several studies have shown that VATS offers advantages when compared to thoracotomy [41–43, 47]. In a prospective randomised study from China, VATS was associated with significantly shorter operating times ($p < 0.05$), less intraoperative bleeding, and a lower postoperative drainage volume in the management of patients with penetrating thoracic trauma [47]. Likewise, VATS is presently the method of choice for the early management (within the first four days of trauma) of patients with retained haemothorax [48]. In spite of the absence of high-quality comparative studies, VATS is increasingly used as the preferred surgical technique in the treatment of haemodynamically stable or stabilised patients with thoracic trauma. For this reason, VATS is recommended as a GPP for the initial surgical management of patients with cardiopulmonary stability.

## Penetrating chest injuries

Apart from the above-mentioned indications for surgical intervention, the Guideline Group recommends that retained foreign bodies should only be removed under controlled conditions in the operating room (GoR B) in order to prevent secondary injuries or the uncontrolled release of any tamponade effect. Patients in a stable haemodynamic and respiratory condition undergo chest tube placement. Further treatment then depends on the results of the diagnostic procedures that must then be performed. The retained foreign body also helps to detect the depth of injury.

Injuries to the lung and the tracheobronchial system.

If surgery is indicated (for ongoing bleeding and/or persistent air leaks) in patients with lung injuries, a parenchyma-sparing approach should be used. (GoR B)

The recommendation to use a parenchyma-sparing technique in the management of lung injuries that require surgery for ongoing bleeding and/or parenchymal fistula [49–51] was confirmed by a retrospective analysis of data from the National Trauma Data Bank [34].

Aiolfi et al. [34] reported a significant increase ($p < 0.001$) in mortality as the extent of resection increased (wedge resection, 20.3%; lobectomy, 30.8%; pneumonectomy, 63.4%; $p < 0.001$). After propensity score analysis, the odds ratio (OR) for mortality was 1.42 (95% confidence interval, 1.26–1.71) in the lobectomy group and 4.16 (95% confidence interval, 2.84–6.07) in the pneumonectomy group. Similarly, anatomical resections were associated with higher complication rates, more mechanical ventilation days, and longer intensive care unit and inhospital lengths of stay [34].

The recommendations in the 2016 Guideline for the management of injuries to the tracheobronchial system remain unchanged. There is a paucity of high-quality literature on these rare and often life-threatening injuries. If a tracheobronchial injury is suspected, tracheobronchoscopy should be performed (GoR B**)** to confirm the diagnosis in patients with a pneumothorax that persists in spite of a correctly placed and properly functioning chest drain as well as in patients with subcutaneous emphysema or atelectasis. Penetrating injuries most commonly affect the cervical trachea. Blunt trauma usually involves the intrathoracic portion of the tracheobronchial system, especially the right main bronchus [52–55]. Moreover, injuries in the region of the posterior wall of the trachea can occur during tube intubation [24]. Traumatic tracheobronchial injuries are usually managed surgically. Conservative management can be attempted (GoR 0) to treat small localised bronchial tissue defects (< 1/3 of the circumference) with well adapted bronchial margins [52–55]. If indicated, traumatic tracheobronchial injuries should be surgically managed early after diagnosis (GoR B) since delayed treatment is associated with increased complication rates. Cervical injuries are usually approached through a collar incision and thoracic injuries through a right posterolateral thoracotomy [21]. Nonoperative management of iatrogenic tracheal injuries is often an option in patients with uncomplicated ventilation and patients with superficial or sufficiently covered tears [24]. Stents have no role in the management of tracheobronchial injuries.

## Injuries to the great vessels and the heart

If technically and anatomically possible, endovascular stent grafting should be preferred to open repair in the management of thoracic aortic ruptures. (GoR B)

The timing of aortic rupture management depends on the haemodynamic status of the patient at the time of admission. Patients who are haemodynamically unstable (as a result of an aortic injury) and patients in extremis must undergo immediate surgery [56]. The standard treatment of aortic rupture consists of aortic repair using a direct suture with aortic clamping and a variety of bypass techniques allowing for perfusion of the lower body and the spinal cord during clamping (left-heart bypass, Gott shunt, heart-lung machine) [17, 22].

In the management of patients who do not require immediate life-saving surgery, the use of stent grafts for aortic rupture is a minimally invasive and time-saving therapeutic option that minimises damage from the surgical approach [57]. Compared with other surgical techniques, endovascular stenting was reported to be associated with the same technical success rate and significantly lower rates of mortality, postoperative neurological deficits (paraplegia, stroke) and other complications [23, 27, 57]. Based on the available evidence, the recommendation in the 2016 Guideline for aortic stent grafting in the management of traumatic aortic injuries was confirmed.

In patients requiring no immediate intervention, the timing of the management of aortic injuries depends on concomitant injuries. In patients with concomitant traumatic brain injury, severe abdominal or skeletal injuries that require immediate surgical intervention and in elderly patients with serious cardiac and pulmonary comorbidities, aortic repair may be delayed until other life-threatening injuries have been managed or the patient has been stabilised. This approach does not have any disadvantages for the patient [40, 56, 58].

When surgery is not performed as an emergency, strict pharmacologic control of blood pressure (a systolic blood pressure around 100 mmHg and a pulse < 100) with beta-blockers and vasodilators is recommended [18, 58]. Comparative prospective studies on blood pressure control are not available. The European Society of Cardiology (ESC) Guidelines recommend that mean blood pressure should not exceed 80 mmHg [59].

## Injuries to the heart

As a result of the lack of evidence in the available literature, the Guideline Group did not submit any agreed recommendations on cardiac injuries.

The literature emphasises, however, that cardiac injuries are associated with high mortality and require urgent attention [37, 38]. Sternotomy is usually the primary approach to gain access to the heart in an emergency. If anterolateral thoracotomy is used for access in an unclear situation, the incision can be extended to a clam shell thoracotomy in an acute emergency setting. Rapid bleeding control is important after immediate relief of life-threatening cardiac tamponade. Atrial injuries can be repaired by using sutures after the involved atrial wall is clamped [21]. The control of bleeding in more extensive injuries with structural defects of the heart usually requires the use of a heart-lung machine. Ventricular lesions in particular often require the successful use of a heart-lung machine. In such a situation, temporary occlusion can be achieved with a Foley catheter balloon that is inflated in the ventricle.

## Injuries to the bony part of the thoracic wall (without the spine)

In polytrauma patients, these injuries are usually not managed during initial surgical procedures but at a later stage following patient stabilisation. The Guideline Group did not submit any agreed recommendations on these injuries.

## Limitations of the guideline

Patient values and preferences were sought but not received. The effect of this on the guideline is unclear, and there is a lack of research evidence on the effect of patient participation on treatment decisions or outcomes in the emergency setting.

## Risk-of-bias assessment for included studies and levels of evidence

The study included in the update showed an unclear risk of performance and detection bias. The level of evidence was not downgraded for any study.

## Recommendations

One recommendation was modified. Two additional good practice points were developed based on the updated evidence and expert consensus (Table 5. All achieved strong consensus. (Table S5, Online Resource 1).

GoR, grade of recommendation; GPP, good (clinical) practice point; VATS, video-assisted thoracoscopic surgery.

**Table 5** List of recommendations with grade of recommendation and strength of consensus

| No. | GoR | Evidence, consensus[a] | Recommendation | Status 2022 |
|---|---|---|---|---|
| *Key recommendations* | | | | |
| 1 | 0 ⇔ | 100% | Depending on the location of injury, anterolateral thoracotomy or sternotomy can be used to access the chest. If the location of injury is unclear, a clam shell incision can be used. | Confirmed |
| 2 | GPP | 100% | Video-assisted thoracoscopic surgery (VATS) can be used to gain thoracic access or to perform a surgical procedure in patients with cardiorespiratory stability. | **New** |
| 3 | B ⇑ | 100% | In patients with penetrating chest injuries, retained foreign bodies should only be removed under controlled conditions in the operating room after thoracotomy. | Confirmed |
| 4 | A ⇑⇑ | 100% | Patients with a penetrating chest injury that is the cause of haemodynamic instability use immediate exploratory thoracotomy. | Confirmed |
| 5 | GPP | 100% | Thoracotomy can be performed in stable and unstable patients with initially high blood loss or ongoing relevant blood loss through a chest tube. | **Modified** |
| 6 | GPP | 100% | Video-assisted thoracoscopic surgery (VATS) can be performed as an alternative to thoracotomy in patients with cardiopulmonary stability. | **New** |
| 7 | B ⇑ | 100% [34] | If surgery is indicated (for ongoing bleeding and/or persistent air leaks) in patients with lung injuries, a parenchyma-sparing approach should be used. | Confirmed |
| 8 | B ⇑ | 100% | If technically and anatomically possible, endovascular stent grafting should be preferred to open repair in the management of thoracic aortic ruptures. | Confirmed |
| 9 | B ⇑ | 100% | If an injury to the tracheobronchial system is suspected on clinical grounds, tracheobronchoscopy should be performed to confirm the diagnosis. | Confirmed |
| 10 | B ⇑ | 100% | Traumatic injuries to the tracheobronchial system should be surgically managed early after diagnosis. | Confirmed |
| 11 | 0 ⇔ | 100% | Conservative management can be attempted to treat localised injuries to the tracheobronchial system. | Confirmed |

## Abbreviations

| | |
|---|---|
| AAST | American Association for the Surgery of Trauma |
| AIS | Abbreviated Injury Scale |
| AWMF | German Association of the Scientific Medical Societies |
| CG | Control group |
| ESC | European Society of Cardiology |
| GoR | Grade of recommendation |
| GPP | Good (clinical) practice point |
| IG | Intervention group |
| ISS | Injury Severity Score |
| LoE | Level of evidence |
| mL | Millilitre |
| n.r.: | Not reported |
| OR | Odds ratio |
| PICO | Population, intervention, comparison, outcome |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| RCT | Randomised controlled trial |
| RoB | Risk of bias |
| RR | Risk ratio |
| SBP | Systolic blood pressure |
| Unadj | Unadjusted |
| VATS | Video-assisted thoracoscopic surgery |
| Y | Years |

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**Author contributions** All authors contributed equally to this work. B.P. and J.B. conducted the systematic literature search and reduced the data. C.S., J.B. and B.P. (methods section) wrote the main paper. All authors devised the concept, interpreted and discussed the results, discussed its implications and the recommendations, and commented on the manuscript at all stages. All authors contributed extensively to the work presented in this paper.

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**Data availability** A full version of the guideline and its methods/evidence report are available online at https://register.awmf.org/de/

leitlinien/detail/187-023.

## Declarations

**Ethical approval** Was not required because the study used publicly accessible documents as evidence.

**Competing interests** The authors declare no competing interests.



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