Imaging Evaluation in the Early Management of Severely Injured Patients.

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Research Article

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Abstract

Introduction: The plain film chest x-ray in supine position (CXR) during the initial management of severely injured patients has almost lost its clinical relevance, since it has been challenged by extended focused assessment with sonography in trauma (eFAST) in early trauma management, due to its superiority in detecting a pneumo-/hematothorax. One of the last diagnostic fields in such setting of CXR is the mediastinal vascular injury. These injuries are rare yet life-threatening events. The most easily accessible diagnostic tool to identify these patients would be CXR as it is still one of the standard diagnostic tools in the early assessment of severely injured patients with significant thoracic trauma (Abbreviated Injury Scale, AIS ≥3). This study evaluates the role of early CXR in the Trauma Resuscitation Unit (TRU) in the last diagnostic field where eFAST cannot provide an answer: detecting mediastinal vascular injury in severely injured patients.

Method: This retrospective, observational, single-centre study included all primary blunt trauma patients of a 24 months time period, that had been admitted to the TRU. Mediastinal/chest (M/C) ratio measurements were taken from CXRs at three defined levels of the mediastinum. The accuracy of the CXR findings were compared to whole-body computed tomography scans (WBCT) and therapeutic consequences were observed. Additionally a 15 years (2005–2019) time period out of the TraumaRegister DGU® was evaluated regarding usage of eFAST, CXR und WBCT in Level-1, -2, and – 3 Trauma Centres in Germany.

Results: A total of 267 patients showed a significant blunt thoracic trauma (27 with mediastinal vascular injury (VThx)). The initial CXR in a supine position was unreliable for detecting mediastinal vascular injury. The sensitivity and specificity at different thresholds of maximum M/C ratio (2.0–3.0) were not clinically acceptable. The aortic contour and haemato- and pneumothorax were not reliably detected in the initial CXRs. No significant differences in the cardiac silhouette were observed between patients with or without mediastinal vascular injury (mean cardiac width, 136.5 mm, $p = 0.44$). No therapeutic consequences were drawn after CXR in the study period. The data from the TR-DGU ($N = 251{,}095$) showed a continuous reduction of CXR from 75% (2005) to 25% (2019), while WBCT raised from 35% to a steady level of about 80%. This development was seen in all trauma hospitals almost simultaneously.

Conclusion: In present guidelines, CXR remains an integral diagnostic element during early TRU management, although several prior publications show the superior role of eFAST. Our data support that in most cases, CXR is time consuming and provides no benefit during initial management of severely injured patients and might delay the use of WBCT. The trauma centres in Germany have already significantly reduced the usage of CXR in the TRU. We therefore recommend to revise current guidelines and emphasise eFAST and rapid diagnostic through WBCT if rapidly available.

Introduction

Time and highly efficient management is of the essence in severely injured patients. Complete assessment of the pattern of injury is important for rapid decision making regarding further treatment of the patient. CXR is one of the early adjuncts that can support the Trauma Team in the Trauma Resuscitation Unit (TRU) in fulfilling its goal in the management of severely injured. Next to clinical examination, objective diagnostic tools can verify the findings. While CXR accounts for a very significant proportion of imaging throughout the world, it often represents the first imaging step besides sonography in trauma management. But especially blunt chest trauma leading to mediastinal vascular injury still ranks among the most serious clinical problems due to the difficulties of initial diagnostics performed in the TRU combined with a dramatically high mortality rate within the first hour after injury[26]. While thoracic vascular injury is a rare event, at the same time, blunt chest trauma with an Abbreviated Injury Scale (AIS) ≥3 is one of the leading diagnoses in severely injured patients[4]. The initial management of these patients is a critical period, combining the urge of a thorough injury assessment with finding the sources of instability, stabilizing vital functions, and defining a therapeutic strategy. An easily accessible and highly sensitive diagnostic tool to disprove the presence of a mediastinal injury is crucial. Thus, the Committee on Trauma of the American College of Surgeons retains CXR in the 10th edition of its Advanced Trauma Life Support (ATLS) manual on management of severely injured patients, although prompt surgical therapy may be lifesaving in patients with mediastinal bleeding[3].

Especially in completely unstable patients i.e. with mediastinal vascular injury, the decision to obtain further diagnostic testing or to initiate immediate surgery is commonly based on the history of the patient and the early CXR findings. Several radiographic findings in CXRs have been evaluated in the past century to detect aortic rupture or mediastinal bleeding such as mediastinal widening, abnormal aortic contour, rib and other bone fractures, pneumothorax, haematothorax, and pulmonary contusion[8, 13, 17, 18, 27]. While these criteria still exist, members of the trauma teams apparently are no longer trained to detect such findings due to the rising prevalence of eFAST and whole body computed tomography scan (WBCT). The role of CXR in detecting pneumo- and haematothorax has been challenged in the past decade. The eFAST has proven to be the superior diagnostic modality in initial trauma management[1, 2, 8, 19, 23]. While the growing role of eFAST in the initial trauma management and WBCT have changed the clinical trauma algorithms, no corresponding update has been made to the guidelines. The combination of eFAST and the clinical evaluation of the patients can safely direct them towards immediate WBCT without further diagnostics such as CXR[13]. While the diagnostic performance of eFAST is convincing in the context of trauma[1, 2, 8, 9, 19, 23] and CXR is performed in the supine position due to the need for spine immobilization, eFAST though is unable to securely detect mediastinal vascular injury, while CXR might not provide reliable information.

The aim of the study was to evaluate the role of early CXR to detect mediastinal vascular injury in the TRU in severely injured patients and to investigate if any consequences of CXR have been drawn when eFAST and WBCT are immediately available.

Methods

A retrospective, observational, single-centre study that included all patients with primary blunt trauma who had been admitted to the TRU with suspicion of severe injury/multiple trauma between January 1st 2013 and December 31st 2015, with eFAST, CXR and WBCT performed in the TRU. In all CXR, the mediastinal width ratio was measured retrospectively at three levels (Fig. 1). All patients underwent initial physical examinations, eFAST (assessing abdomen, pelvis, pericardium and pleura) and plain film CXR before a WBCT was performed.

The study was approved by the ethics committee at University Medical Centre Goettingen (DOK_121-2016), while informed consent for the use of data of all participating patients existed. All methods were performed in accordance with the guidelines and regulations of the German ethics committee as well as the General Data Protection Regulation of the European Union.

Protocol

The University Hospital of Göttingen level 1 trauma centre is a 1,500-bed institution in the centre of Germany. An average of 900 trauma patients get admitted to the TRU each year. All patients admitted to the TRU are suspected to be severely injured, according to the regional triage system as described in Spering et al. (2018)[29]. The standard trauma care at the hospital is in concordance with the ATLS protocol and the German recommendations of the German Trauma Society (2016)[3,22]. It includes an initial survey with imaging (CXR and/or eFAST), resuscitation, and a WBCT scan for complete injury assessment.

Within 5 min after admission to the TRU, all patients undergo a complete physical examination and an eFAST and / or plain film CRX. The eFAST, including the assessment with sonography of the abdomen, pelvis, pericardium, and pleura, is performed by the trauma leader.

In the first step of the study, we retrospectively examined all CXR that had been taken during TRU management of the patients. After review of quality and diagnostic matters, three measurement levels were obtained to calculate the mediastinal/chest (M/C) ratio (Fig. 1) including:

- The width of the mediastinum at the aortic arch (A’) and the width of the chest at the same level (B’);
- The width of the mediastinum at the valve level (A) and the width of the chest at the same level (B); and
- The width of the cardiac silhouette (a) and the width of the chest at the same level (b).

Two populations were identified when matching the patients’ data with the WBCT findings: those with mediastinal vascular injury (Vthx) (N=27) and those with significant blunt thoracic injury without thoracic vascular injury (Control) (N=240).

The WBCT scan was considered as the “gold standard” for the diagnosis of vascular mediastinal injury if the patient was hemodynamically stable.

In a following observation the data regarding diagnostic findings as well as the decisions that had been made were identified and linked to the official radiologist's findings from the WBCT. Consequences that were undertaken before WBCT, such as chest drainage, were documented.

After data anonymization and data bank acquisition, statistics were performed using an Excel spreadsheet (Microsoft Excel for Mac 2011; V. 14.3.4; Microsoft Redmond, Washington), SPSS (V. 23.0.0; IBM SPSS Statistics SPSS Inc., Chicago, Illinois), and Statistica (V. 12.7; StatSoft, Tulsa, Oklahoma). Data were categorized into nominal, metric, and ordinal levels. For nominal levels, the following tests were applied to show significance: Fisher exact test, Pearson Chi square, and M-L Chi square. For the metric level, t-test or Mann-Whitney-U-Test was applied, while for ordinal data only the Mann-Whitney-U-Test was applied. After the first analysis, significance was considered as a p-value of <0.05, and the Bonferroni method was used afterwards, resulting in a p-value of 0.002381.

Receiver operating characteristic curve (ROC-curve) were calculated with the Youden Index to identify optimal sensitivity and specificity in different mediastinal/chest ratios (M/C ratio).

To identify the usage of CXR over time within German trauma centres, data has been acquired from the TraumaRegister DGU® (TR-DGU)[30]. Primary admitted patients with serious injuries (need for intensive care) documented in the years 2005-2019 were analysed regarding diagnostic procedures in the emergency room. Access to these data have been approved by the AUC – Academy for Trauma Surgery (AUC, Munich).

Results

1733 trauma patients were admitted to the TRU with complete recording during the study time period, including 658 blunt thoracic trauma patients. Of these, 267 showed significant thoracic injury (AIS $\geq$ 3) and fulfilled the inclusion criteria (Fig. 1). The demographic and clinical characteristics of the patients are listed in Table 1.

Table 1
Demographic and clinical characteristics.

	Mediastinal vascular injury (VThx) N = 27	Thoracic injury without vascular injury (control) N = 240
Age (years)	45	50
Males (%)	85	76
ISS (points)	23	48
Mechanism of injury		
• Road traffic accident (%)	52	67
• Fall	40	26
• Others	8	7
Mortality (%)	18.2	8.4

Patients with mediastinal vascular injury showed no significant elevation of the M/C-ratio. In measurement A/B, the ratio showed a median of 0.3 in both groups. In measurement A'B', the ratio was slightly higher in the VThx group, at 0.3 versus 0.29 (Fig. 2).

Since Seltzer et al. (1981)[27] suggested that a M/C ratio at the aortic arch > 0.25 is highly likely to be indicative of an aortic rupture in trauma patients, we tested our data again concerning specificity and sensitivity. If a M/C-ratio of 0.2 was considered pathological, we would have diagnosed a pathological result in 97% of our patients (258 out of 267). This equates to a false positive finding in 233 patients who did not have a mediastinal vascular injury, and a specificity of 2.9%. At a M/C ratio of 0.25, it would still have been 78% positive with a specificity of 23% and sensitivity of 82%. At a M/C ratio of 0.28, the result was still unsatisfactory, leading statistically to a ratio of 0.3 with the best ratio regarding sensitivity to specificity (Table 2). At the mediastinal valve level (measurement A/B), a ratio of 0.28 showed the statistically best ratio of sensitivity to specificity (Table 3), although none of them reached the result described by Seltzer et al. (1981)[27]. Additionally, none showed clinically acceptable sensitivities or specificities for mediastinal vascular injury as shown in Fig. 3–5.

Table 2
Mediastinal/chest ratio (M/C ratio) at A’/B’.

M/C-ratio A’/B’				
Ratio:	**≥ 0.2**	**≥ 0.25**	**≥ 0.28**	**≥ 0.3**
Sensitivity	92.6%	81.5%	70.4%	56 %
Specificity	2.9%	22.5%	43.3%	63.3 %
Positive predictive value	9.7%	10.6%	12.3%	14.6%
Negative predictive value	77.8%	91.5%	92.9%	92.7%

Table 3
Mediastinal/chest ratio (M/C ratio) at A/B.

M/C-ratio A/B				
Ratio:	**≥ 0.2**	**≥ 0.25**	**≥ 0.28**	**≥ 0.3**
Sensitivity	100%	85.2%	63%	44.4 %
Specificity	0.4%	16.7%	38.3%	52.9 %
Positive predictive value	10.2%	10.3%	10.3%	9.6%
Negative predictive value	100%	90.9%	90.2%	89.4%

After having performed the Youden Index and calculated the Receiver Operating Characteristic Curve (ROC) to identify the optimal ratio of sensitivity to specificity (Figs. 4 and 5) (see ratios also shown in red in Tables 2 and 3), 0.3 was identified for the mediastinal measurement A’/B’ and 0.28 for mediastinal measurement A/B, which still missed about 44% of the mediastinal vascular injuries.

The measurement of the cardiac silhouette showed a mean cardiac width of 136.5 mm, ranging from 84.6 to 216.5 mm, with no significant differences between the two investigated groups ($p = 0.44$ after Fischer exact test).

In the evaluation of drawn consequences out of diagnostic findings in the early TRU-management a total of 141 patients were included in this part of the study. While eFAST had been performed in all patients, it showed 11.8% positive findings (pneumothorax or haematothorax) confirmed by the gold standard, WBCT. The CXR had not been able to detect these pathological findings in the study period (Table 4).

Table 4
Comparison of eFAST and chest x-ray concerning sensitivity and specificity.

	eFAST	Chest x-ray
Sensitivity	80%	18.2%
Specificity	100%	100%
Positive predictive value	100%	100%
Negative predictive value	96.7%	71%

Out of the 141 observed patients, 11 required a chest drain. After CXR and eFAST had been undertaken, 63.6% of the chest drains were immediately installed due to eFAST findings and 36.4% after CT findings. None of the interventions were undertaken after CXR.

Data from the TR-DGU was acquired to identify the usage of CXR in German trauma centres in the initial management of severely injured patients in the TRU over the last 15 years. While WBCT increased almost continuously in the years 2005–2010 it reached a stable plateau at about 80% in the following years. At the same time the usage of CXR decreased continuously over the years. While almost 75% of the patients received a CXR in the TRU in 2005, this value decreased to only 20% of the cases in 2019. The use of sonography has been high in about 80–90% ever since (Fig. 7). This shift of CXR use over the years occurred parallel in all participating trauma centers in Germany (Fig. 8).

Discussion

The results of this study demonstrate that an initial CXR in the supine position is not reliable for detecting mediastinal vascular injury. The sensitivity and specificity when applying different thresholds of maximum M/C-ratio are not clinically acceptable. In addition, the aortic contour and haemato- and pneumothorax were not reliably detected in the initial CXR. Although some older publications state that the initial CXR in trauma patients is able to detect a pneumothorax or haemothorax, rib fractures, tracheobronchial injuries, a pneumo-mediastinum, mediastinal haematoma, and lung contusion[12, 17, 20, 27], there is no recent evidence to support these statements[22]. With respect to the diagnosis of mediastinal vascular injuries, different measurements of mediastinal width ratios have been suggested to detect vascular injury. In a retrospective study, Gleeson et al. (2001)[10] were able to show that the 8-cm upper limit for normal mediastinal width no longer applied in the modern trauma room. Changes in the position of the x-ray cassette and the lengthening of the distance between the patient and the x-ray source can significantly reduce magnification. They therefore suggested a new range of upper limits resulting in maximal normal widths between 8.0 and 10.94 cm[10], though absolute measurements show their limits in anatomical relationships.

Therefore, we state that neither the absolute width nor the M/C ratio in the initial CXR are able to detect mediastinal vascular injury in severely-injured patients in the TRU and should only be applied in regard to those limits and interpreted carefully.

Our results could have significant clinical implications. Many authors already suggest omitting the initial CXR and replacing it by eFAST[1, 2, 6, 8, 9, 13, 15, 18, 26]. This is especially true in developed countries where a WBCT is rapidly available and is part of the secondary survey algorithm. In several studies, eFAST was superior in detecting haemothorax, pneumothorax, and pericardial tamponade as an adjunct during the primary survey[2].

Ultrasound of the chest performed best, with a sensitivity of 100% and a specificity of 94%[25]. A recent publication showed a positive predictive value of the ultrasound of 95% and a negative predictive value of 100%[6]. Another retrospective evaluation in 240 patients showed that ultrasound is equal to CXR in detecting a haemothorax[16]. The sensitivity for both was 96% and specificity was 100%.

The results of our study underlines the superior role of eFAST in the TRU, especially regarding decision-making after positive findings such as haemato- or pneumothorax. Thus, eFAST has limitations to detect mediastinal vascular injury due to the sternum occluding the ultrasonic window to the mediastinum as well as in severe emphysema; therefore, it can only be part of the patient's preparation to quickly perform the WBCT. As shown in the presented data, during the early period of trauma management of severely-injured patients, CXR is unable to detect mediastinal vascular injury. Thus, we present one more important argument to omit the initial CXR in the TRU and replace it by eFAST combined with clinical findings and optimal history-taking followed by a WBCT. The CXR only has its two last indications in cardiorespiratory unstable patients who are too unstable for the WBCT and/or who have extensive emphysema of the torso. In regard to these findings, the suggested algorithm for early management in the TRU is shown in Fig. 6.

In developing countries, where WBCT is not immediately available in every trauma centre, it is important to realize that a widened mediastinum (M/C width > 0.3 at the aortic arch) can be an indicator of mediastinal vascular injury, but it is not a proof. At the same time, a normal M/C ratio does not rule out mediastinal vascular injury. Therefore, it is important to consider additional risk factors including the mechanism, severity, and pattern of injury as well as the patient's physiological status and dynamic. In the literature, the following mechanisms of injury have been identified as causing injuries to the aorta: lateral impact in road traffic accidents[14, 21, 24] and high impact trauma in road traffic accidents (speed > 100 km/h)[7]. Patterns of injury that show a correlation with aortic injuries were multiple rib fractures 1-4[28] and sternum fractures[11].

The data from the TR-DGU underline that (1) CXR does not play a major role in the early assessment of multiple injured patients in the TRU anymore and (2) the frequence of CXR decreased in all three trauma levels parallel to an increase of usage of the WBCT independently from the fact if WBCT is immediately available within the TRU or further away. While the quality of diagnostic via sonography has improved over the years, its usage in the TRUs in all Trauma Centres in Germany has been high. The findings from a performed eFAST in the TRU seem to suffice for initial diagnostic before the WBCT is performed.

Conclusion

The presented data show that CXR should be discussed to be replaced by eFAST in the initial management of severely-injured patients since it is time consuming and delays transport to the WBCT. While eFAST is the diagnostic tool for gathering most of the important information underlying lifesaving decisions, history-taking and clinically obtaining the complete status of the patient is as crucial as watching the time to completing the diagnostics. We therefore recommend revising the current guidelines and replacing CXR by eFAST in case of an immediate availability of a WBCT and absence of contraindications i.e. aerodermectasia, including the observed limitations.

Limitations

While there was no senior radiologist present on the TRU team, communications of CXR findings might have been delayed, although a senior orthopaedic trauma surgeon led the TRU team, which also included an anaesthesiologist and a radiologist. Further limitations are the single-centre setting and the retrospective data.

In the presented data we only focused on the measurement of mediastinal widening as a pathological finding in mediastinal vascular injury. The M/C-ratio is only one of the clinical pathologies through which the trauma team could be able to detect mediastinal vascular injury early. Since it is the most obvious pathological finding we did not measure other findings out of the plain film chest x-ray.

Declarations

Ethics approval

The study was approved by the ethics committee at University Medical Centre Goettingen (DOK_121-2016)

Consent for publication

Not applicable

Availability of Data and Materials

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Competing interests

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Author's contribution

CS designed the study, developed the method and wrote most of the manuscript; SDB collected the data and worked on the statistics; BB lined out the method, worked on the statistics and participated in writing the manuscript; MTS contributed to the data collection and the "results"-part in the manuscript; KJ contributed to the literature research and the "discussion" part; WL participated in the study design, outline and writing and correction of the manuscript; RL data acquisition from the TraumaRegister DGU® and manuscript outline; KD participated in the methods and statistics part, guided the outline and data collection and supported the writing of the manuscript; SF participated in the study process, data collection and evaluation of results as well as the manuscript outline

References

1. Abdulrahman, Y. *et al.* Utility of extended FAST in blunt chest trauma: Is it the time to be used in the ATLS algorithm? *World J Surg.* **39**, 172–178 (2015).
2. Alrajab, S. *et al.* Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of the literature and meta- analysis. *Crit Care.* **17**, R208 (2013).

3. American College of Surgeon Committee On Trauma. Advanced Trauma Life Support (ATLS®) 10th edition. 2018
4. Bayer, J. *et al.* Severity-dependent differences in early management of thoracic trauma in severely injured patients - Analysis based on the TraumaRegister DGU®. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine.* **25**, 10 https://doi.org/10.1186/s13049-017-0354-4 (2017).
5. Gleeson, C. E., Spedding, R. L., Harding, L. A. & Caplan, M. The mediastinum-is it wide? Emerg Med J 2001; **18**: 183–185; 2001
6. Dulchavsky, S. A. *et al.* Prospective evaluation of thoracic ultrasound in the detection of pneumothorax. *J Trauma.* **50**, 201–205 (2001).
7. Dyer, D. S. Thoracic aortic injury: how predictive is mechanism and is chest computed tomography a reliable screening tool? A prospective study of 1,561 patients. *J Trauma.* **48**, 673–682 (2000).
8. Ebrahimi, A. *et al.* Diagnostic accuracy of chest ultrasonography versus chest radiography for identification of pneumothorax: a systematic review and meta-analysis. *Tanaffos.* **13**, 29–40 (2014).
9. Gentry Wilkerson, R. & Stone, M. B. Sensitivity of bedside ultrasound and supine anteroposterior chest radiographs for the identification of pneumothorax after blunt trauma. *Acad Emerg Med.* **17**, 11–17 (2010).
10. Gleeson, C. E., Spedding, R. I., Harding, I. A. & Caplan, M. The mediastinum – is it wide? *Emerg Med J.* **18**, 183–185 (2001).
11. Gombert, A. *et al.* Treatment of blunt thoracic aortic injury in Germany— Assessment of the TraumaRegister DGU®. *PLoS ONE.* **12** (3), e0171837 (2017). https://doi.org/10.1371/journal.pone.0171837
12. Greenberg, M. D. & Rosen, C. L. Evaluation of the patient with blunt chest trauma: an evidence based approach. *Emerg Med Clin North Am.* **17**, 41–62 (1999).
13. Hamada, S. R., Delhaye, N., Kerever, S., Harrois, A. & Duranteau, J. Integrating eFAST in the initial management of stable trauma patients: the end of plain film radiography. *Ann. Intensive Care.* **6**, 62 https://doi.org/10.1186/s13613-016-0166-0 (2016).
14. Horton, T. G. *et al.* Identification of trauma patients at risk of thoracic aortic tear by mechanism of injury. *J Trauma.* **48**, 1008–1013 (2000).
15. Hyacinthe, A. C. *et al.* Diagnostic accuracy of ultrasonography in the acute assessment of common thoracic lesions after trauma. *Chest.* **141**, 1177–1183 (2012).
16. Ma, O. J. & Mateer, J. R. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med.* **29**, 312–315 (1997).
17. McLellan, B. A., Ali, J., Towers, M. J. & Sharkey, W. Role of the trauma-room chest x-ray film assessing the patient with severe blunt traumatic injury. *Can J Surg.* **39**, 36–41 (1996).
18. Nagarsheth, K. & Kurek, S. Ultrasound detection of pneumothorax compared with chest X-ray and computed tomography scan. *Am Surg.* **77**, 480–484 (2011).

19. Nandipati, K. C. *et al.* Extended Focused Assessment with Sonography for Trauma (eFAST) in the diagnosis of pneumothorax: experience at a community based level I trauma center. *Injury.* **42**, 511–514 (2011).
20. O'Connor, J. V., Byrne, C., Scalea, T. M., Griffith, B. P. & Neschis, D. G. Vascular injuries after blunt chest trauma: diagnosis and management. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine.* **17**, 42 https://doi.org/10.1186/1757-7241-17-42 (2009).
21. Pattimore, D., Thomas, P. & Dave, S. H. Torso injury patterns and mechanisms in car crashes: an additional diagnostic tool. *Injury.* **23**, 123–126 (1992).
22. Polytrauma Guideline Update Group. Level 3 guideline on the treatment of patients with severe/multiple injuries. *European Journal of Trauma and Emergency Surgery.* **44** (Suppl 1), S3–S271 (2018).
23. Reissig, A. & Kroegel, C. Accuracy of transthoracic sonography in excluding post-interventional pneumothorax and hydropneumothorax: comparison to chest radiography. *Eur J Radiol.* **53**, 463–470 (2005).
24. Richter, M. *et al.* Correlation between crash severity, injury severity, and clinical course in car occupants with thoracic trauma: a technical and medical study. *J Trauma.* **51**, 10–16 (2001).
25. Rowan, K. R. *et al.* Traumatic pneumothorax detection with thoracic ultrasound: correlation with chestradiography and CT initial experience. *Radiology.* **225**, 210–214 (2002).
26. Sauter, T. C., Hoess, S., Lehmann, B., Exadaktylos, A. K. & Haider, D. G. Detection of pneumothoraces in patients with multiple blunt trauma: us and limitations of eFAST. *Emerg Med J.* **34**, 568–572 (2017).
27. Seltzer, S. E., D'Orsi, C., Kirshner, R. & DeWeese, J. A. Traumatic Aortic Rupture: Plain Radiographic Findings. AJR(1981); **137**:1011–1014
28. Siegel, J. H., Smith, J. A. & Siddiqi, S. Q. Change in velocity and energy dissipation on impact in motor vehicle crashes as a function of the direction of crash: key factors in the production of thoracic aortic injuries, their pattern of associated injuries and patient survival. A Crash Injury Research Engineering Network (CIREN) study. *J Trauma.* **57**, 760–777 (2004).
29. Spering, C. *et al.* Optimized resource mobilization and quality of treatment of severely injured patients through a structured trauma room alarm system. *Unfallchirurg.* **121**, 893–900 (2018).
30. www.traumaregister-dgu.de

Figures

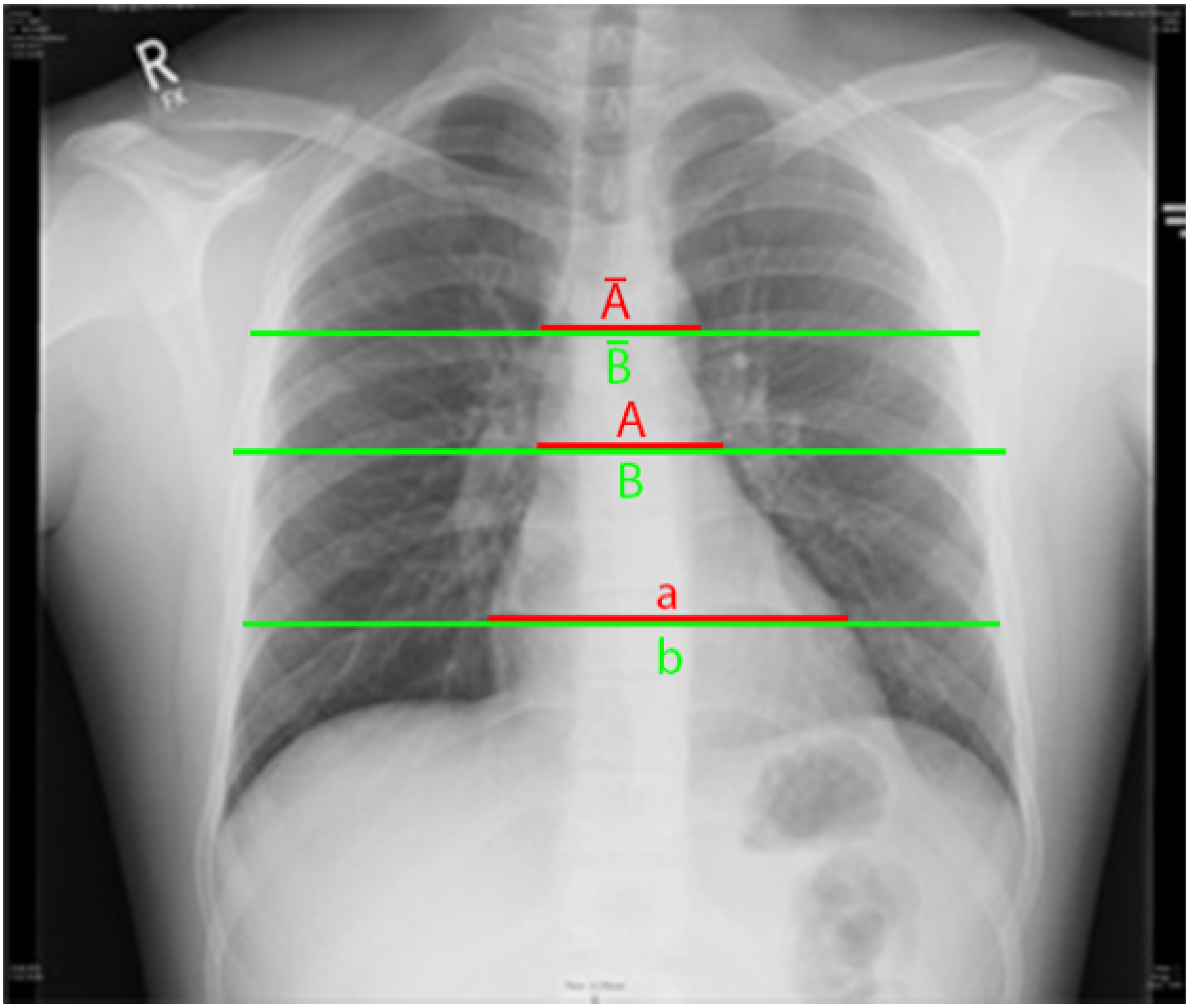

Figure 1

Measurement of mediastinal to chest width (M/C-ratio) at the aortic arch (A'/B'), valve area (A/B), and cardiac silhouette (a/b).

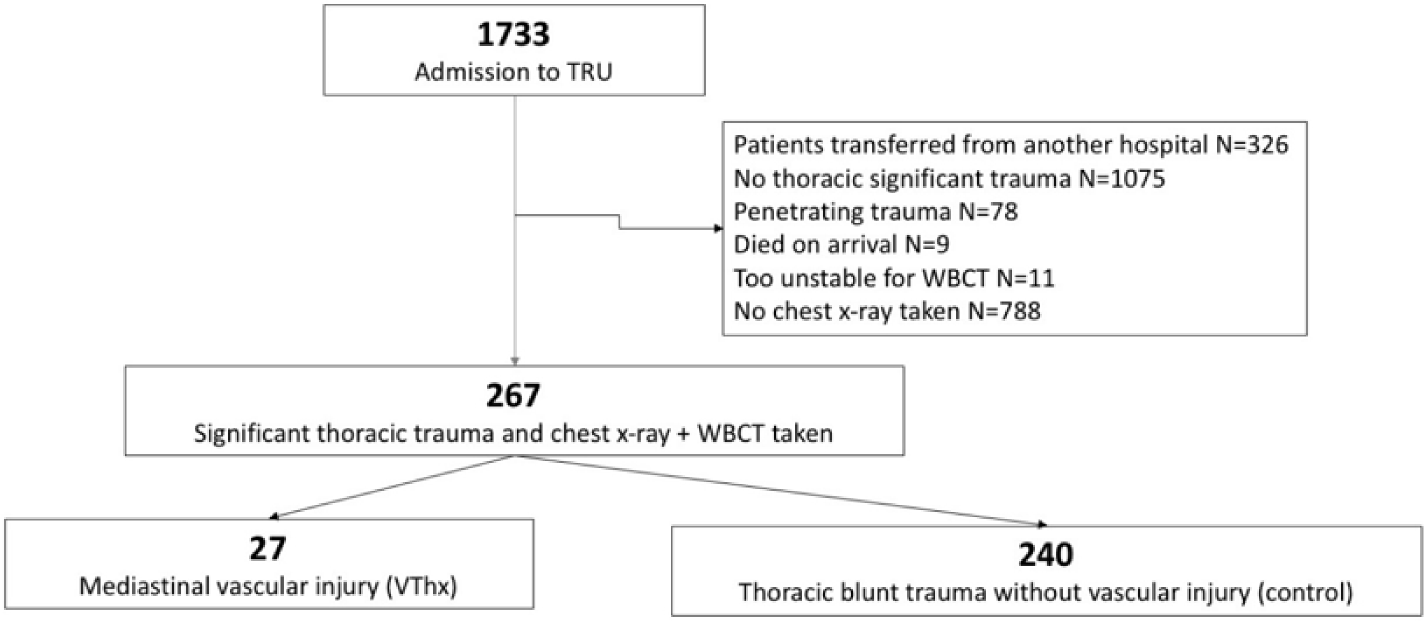

Figure 2

Flow chart of the study. WBCT - whole body computed tomography scan.

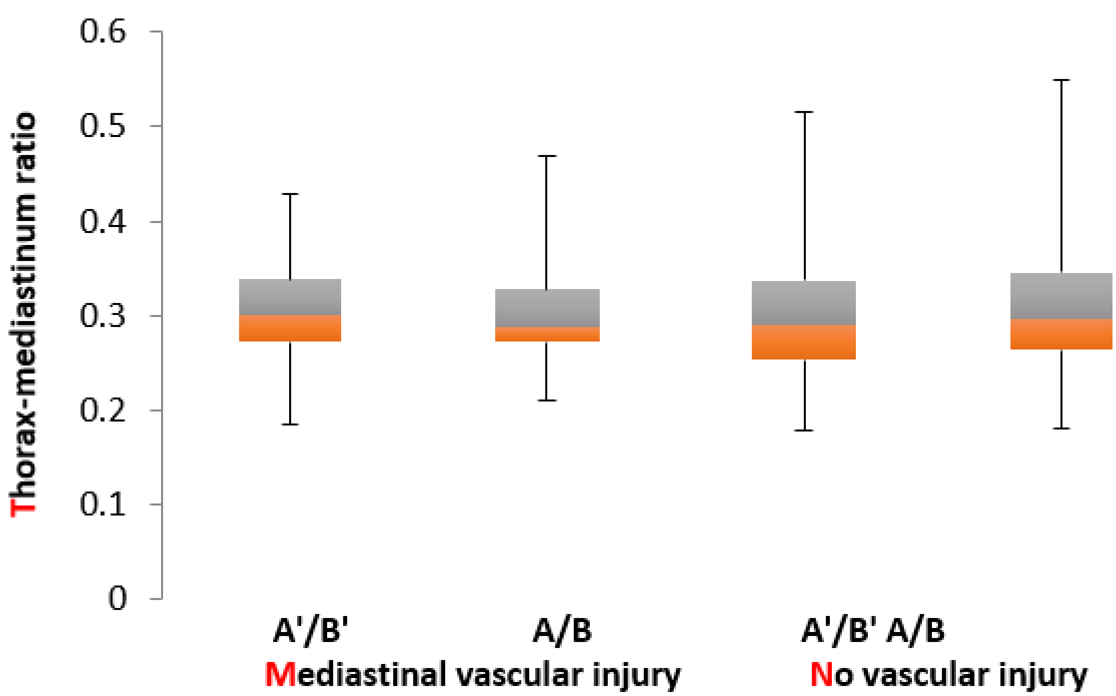

Figure 3

Thoracic-mediastinal ratio in patients with (N=27) and without (N=240) mediastinal vascular injury.

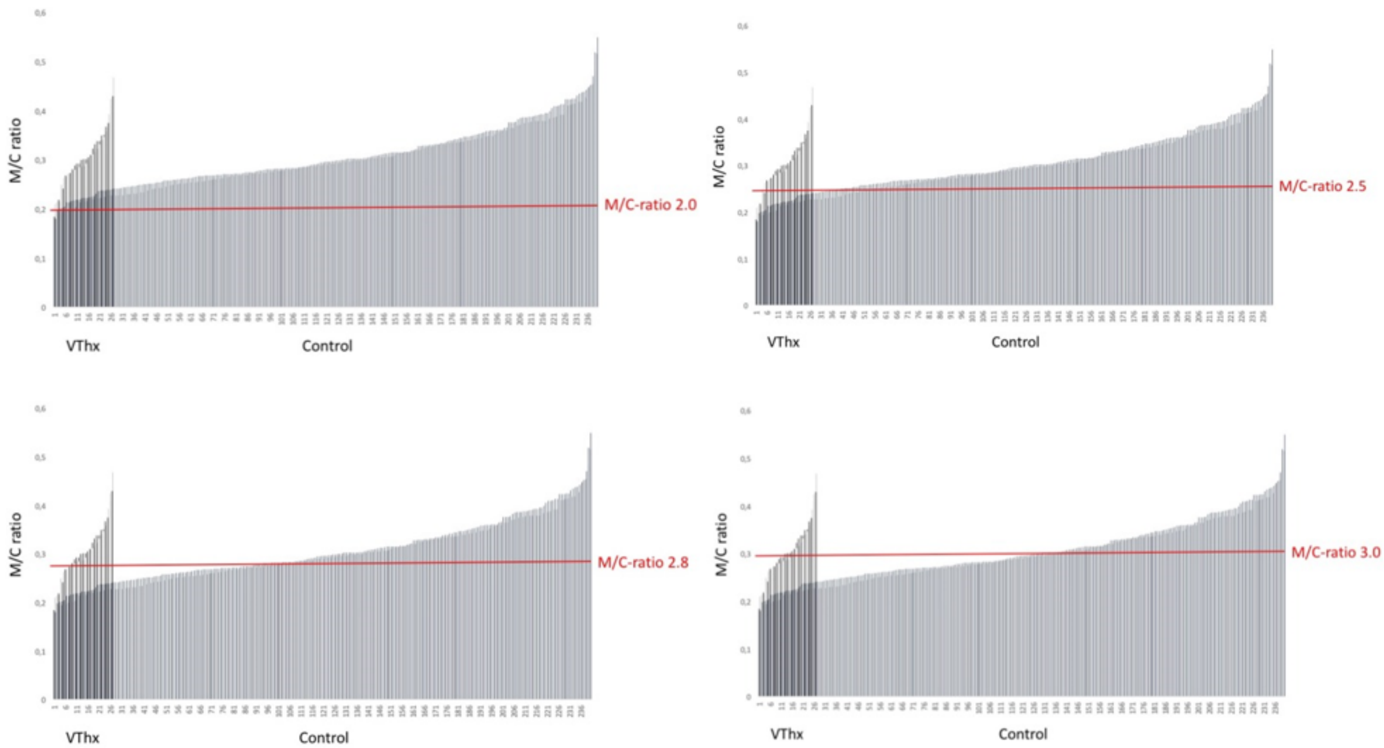

Figure 4

All mediastinal/chest (M/C) ratios at measure points A'/B' and A/B in patients with vascular mediastinal injury (VThx) and the control patients are shown, with threshold M/C ratios of 2.0, 2.5, 2.8, and 3.0.

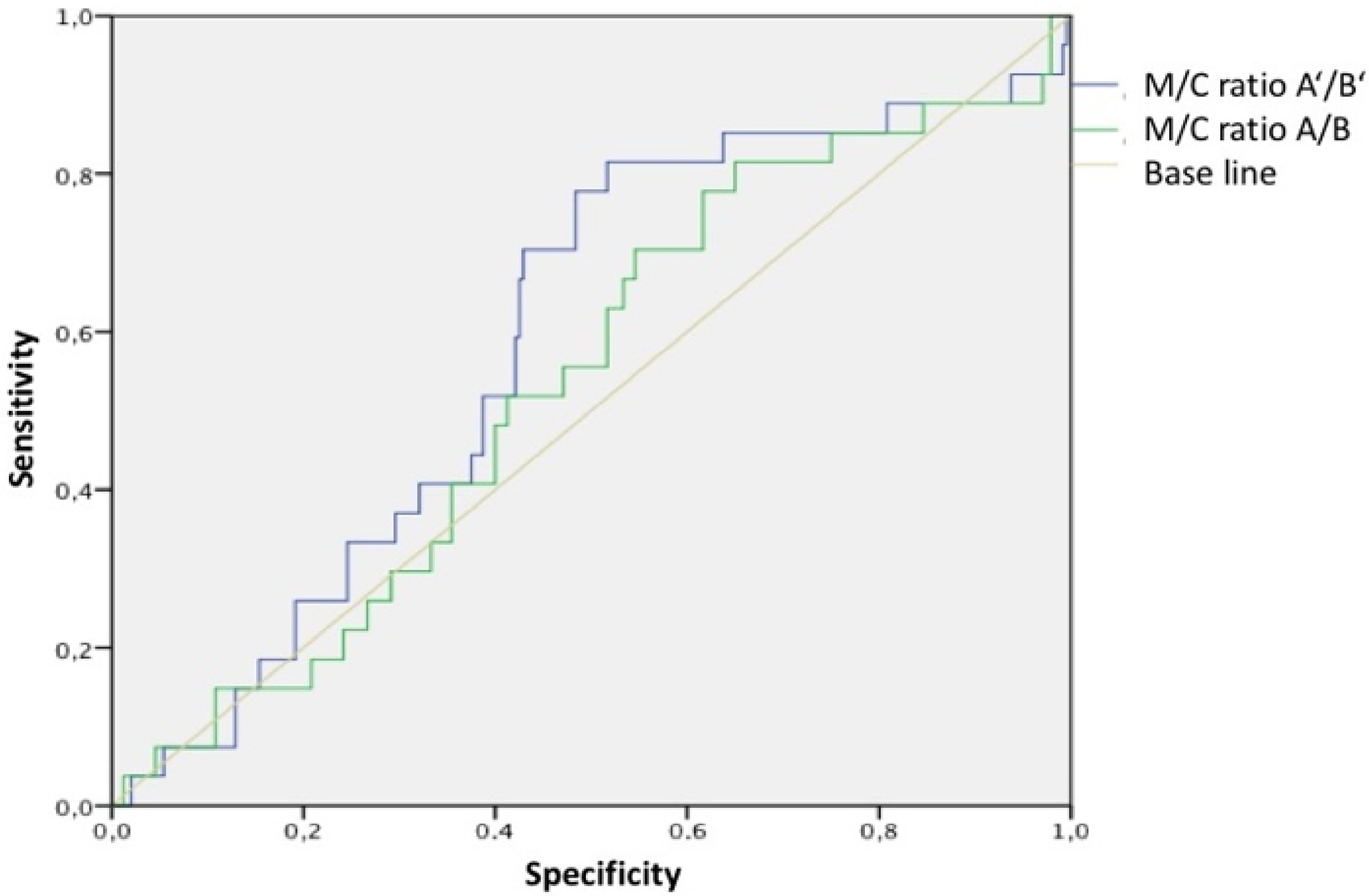

Figure 5

Receiver operating characteristic curve after Youden Index to identify optimal sensitivity and specificity. mediastinal/chest ratio (M/C ratio) at A'/B' is 0.3 and at A/B is 0.28.

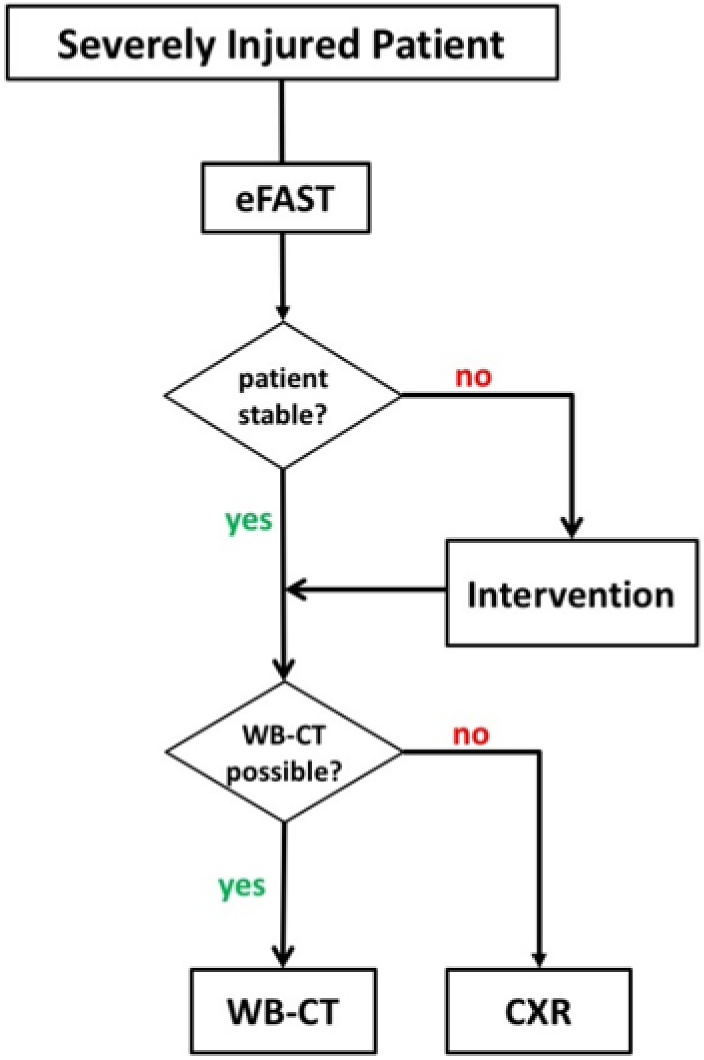

Figure 6

Flow chart for clinical decision-making in the diagnostic pathway during trauma management in the TRU, treating cardiorespiratory stable versus unstable patients. It includes one single remaining indication for undertaking a CXR in the TRU, especially in cardio respiratory unstable patients. CXR – plain film chest x-ray in the supine position; WB-CT – whole body computed tomography scan.

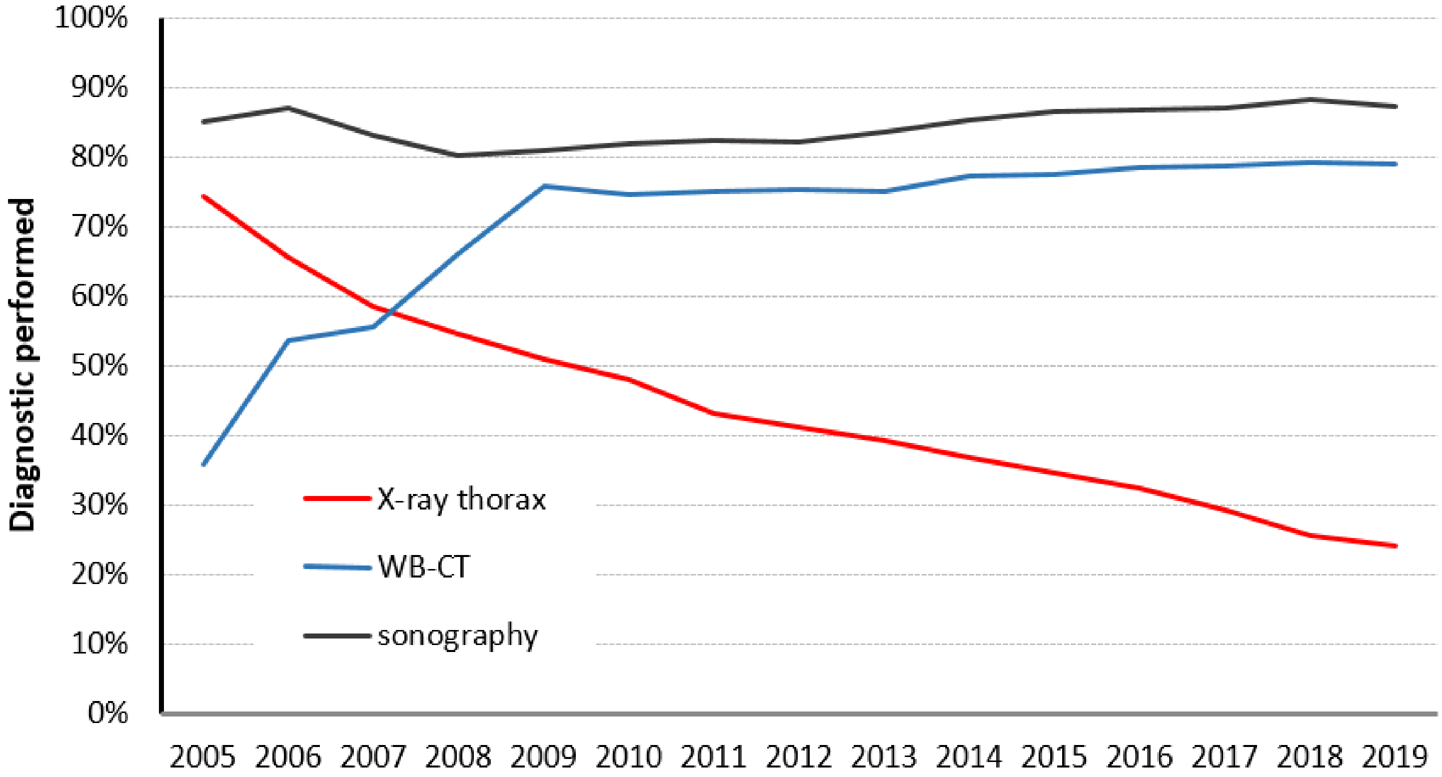

Figure 7

Frequency of different diagnostic procedures in severely injured trauma patients over time (data from TR-DGU, Germany 2005-2019, n=251,095 primary admitted patients).

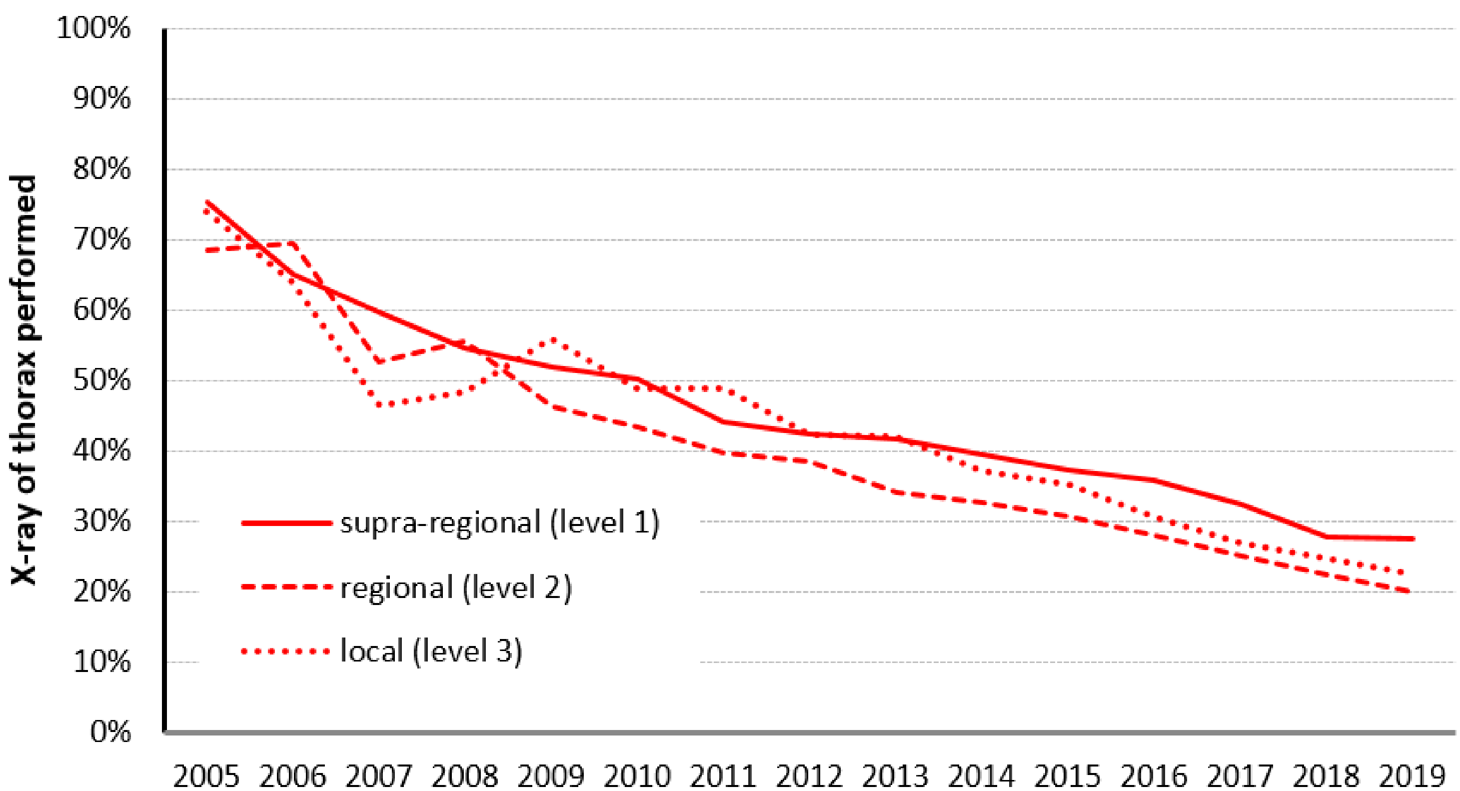

Figure 8

The use of CXR in different trauma center level (data from TR-DGU, Germany 2005-2019, n=251,095 primary admitted patients).