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CHEST IMAGING

ORIGINAL ARTICLE

Diagnostic value of portable handheld digital radiography in a beagle model of thoracic trauma

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PURPOSE

To assess the diagnostic value of portable handheld digital radiography (DR) in a beagle model of thoracic trauma.

METHODS

Twenty-seven beagles were randomly assigned to three experimental groups: the pneumothorax group (induced by intrapleural air injection at 50 mL/kg), the pleural effusion group (induced by intrapleural normal saline injection at 30 mL/kg), and the rib fracture group (created by surgical transection of the 6th rib). All animals underwent three imaging examinations in a randomized order: conventional chest X-ray, mobile DR, and portable handheld DR. Detection rates (using surgical outcomes as the gold standard), image quality, and total examination time (from positioning to image acquisition) were compared among the three modalities.

RESULTS

A total of 21 animals completed the full protocol (7 per group). There was no significant difference in detection rates among the three examination methods ($P > 0.050$). The image quality of both mobile DR and portable handheld DR was significantly superior to that of conventional chest X-ray ($P = 0.021$). Examination times for mobile DR (8.37 ± 0.80 minutes) and portable handheld DR (7.07 ± 0.67 minutes) were significantly shorter than for conventional chest X-ray (10.40 ± 0.96 minutes) ($P < 0.001$). Furthermore, portable handheld DR had a significantly shorter examination time than mobile DR ($P < 0.05$).

CONCLUSION

Portable handheld DR provides detection rates comparable with mobile DR and conventional chest X-ray for thoracic trauma, with the advantages of superior image quality over conventional chest X-ray and the shortest examination time. Its user-friendly operation and high portability make it a valuable tool for emergency imaging in austere environments.

CLINICAL SIGNIFICANCE

Based on diagnostic results in a beagle model of thoracic trauma, this study demonstrates that portable handheld DR can provide reliable methodological support for real-time imaging and rapid triage in harsh environments such as field and post-disaster settings.

KEYWORDS

Portable handheld digital radiography, thoracic trauma, emergency rescue, diagnostic value, canine model

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Thoracic trauma often leads to varying degrees of damage to multiple organs and systems, presenting as critical and complex conditions with a high mortality rate. Because it frequently involves compound injuries, symptoms can easily mask each other, posing major challenges for diagnosis and treatment.[1] Such injuries may include rib fractures, pulmonary contusions, and pneumothorax, characterized by rapid onset and progression and often involving multiple injuries.[2] If not diagnosed and treated promptly, they can lead to severe complications such as massive hemorrhage, infection, or shock. Therefore, rapid and early diagnosis, along with effective treatment, are critical for saving lives, and there is an urgent need for quicker and more efficient diagnostic methods to improve treatment success rates.

Digital radiography (DR) is a commonly used conventional imaging technique widely applied in the diagnosis of acute thoracic trauma. It features low cost, fast examination speed, clear images, good contrast, simple operation, and low radiation dose. It can assist in diagnosis through various image post-processing functions.[3] However, in special scenarios such as field rescue, emergency response at primary healthcare facilities, and disaster sites in remote areas, large-scale equipment such as chest DR and computed tomography scanners is bulky and immobile, relying on fixed power sources and professional operating environments, which makes them difficult to rapidly deploy and use for examinations.[4] Although conventional DR is relatively common in clinical applications, its limited portability restricts its widespread use in emergency medical rescue. In contrast, portable DR considerably enhances equipment mobility and utilization efficiency, opening up a new direction for the development of emergency medical rescue equipment. In this context, how to utilize accessible small-scale portable imaging devices on-site to achieve rapid preliminary diagnosis has become a critical issue in improving the efficiency of emergency medical treatment.

This study systematically investigates the diagnostic value of portable handheld DR in acute thoracic trauma using a beagle model, with the primary objective of delivering efficient and convenient imaging support for battlefield casualties with thoracic trauma, thereby enhancing diagnostic capabilities for injured patients.

Main points

- This study directly compares portable handheld digital radiography (DR), mobile DR, and conventional chest X-ray in beagle models of pneumothorax, pleural effusion, and rib fracture.
- Key findings demonstrate that although all three methods show comparable diagnostic accuracy, portable handheld DR offers significantly superior image quality compared with conventional chest X-ray and the shortest examination time among all modalities.
- These results confirm the high clinical value of portable handheld DR. Its combination of diagnostic efficacy, speed, and portability provides crucial support for emergency imaging in challenging environments, such as disaster zones and field medicine.

Methods

Experimental animals

A total of 27 beagles aged 1–2 years and weighing 12–15 kg were purchased from the Henan Provincial Experimental Animal Center (Zhengzhou, China). All experimental procedures were conducted in accordance with the National Institutes of Health Guidelines for the Care and Use of Laboratory Animals. The animals were housed individually in a barrier facility under controlled environmental conditions: temperature 22 °C ± 2 °C, relative humidity 50%–60%, and a 12-hour light–dark cycle. They had free access to water and were fed a standard canine diet at regular times daily. A 7-day acclimatization period was provided before the experiment.

The sample size of 27 beagles was determined based on animal availability and adherence to the 3R principles. This sample size was consistent with those used in similar exploratory studies in the field of veterinary imaging.

Experimental methods

The experimental protocol was approved by the Ethics Committee of the 988th Hospital of the Joint Logistic Support Force of the People's Liberation Army (decision number: 988YY20240033LLSP, date: March 6, 2024). All experimental procedures strictly complied with the Regulations for the Administration of Laboratory Animals and the Animal Research: Reporting of *In Vivo* Experiments guidelines to minimize animal suffering.

Animal model establishment

Pneumothorax model (n = 9): Beagles were intravenously anesthetized with propofol (6–8 mg/kg) and underwent endotracheal intubation, with anesthesia maintained using 1.5%–2.5% isoflurane. During the procedure, heart rate, blood pressure, respiratory rate, oxygen saturation, electrocardiogram (ECG), and body temperature were continuously monitored. Butorphanol (0.2–0.4 mg/kg) was administered for analgesia. The beagles were placed in the left lateral decubitus position. A puncture drainage catheter was used to perform thoracentesis in the right sixth intercostal space. Filtered air was slowly injected into the pleural cavity at a volume of 3–5 mL/kg using a 50-mL syringe. After catheter removal, the puncture site was sealed with adhesive tape.

Pleural effusion model (n = 9): Beagles were intravenously anesthetized with propofol (6–8 mg/kg) and underwent endotracheal intubation, with anesthesia maintained using 1.5%–2.5% isoflurane. Intraoperative monitoring included heart rate, blood pressure, respiratory rate, oxygen saturation, ECG, and body temperature. Butorphanol (0.2–0.4 mg/kg) was administered for analgesia. The beagles were positioned in the left lateral decubitus position. Thoracentesis was performed in the right sixth intercostal space using a puncture drainage catheter. Normal saline was slowly injected into the pleural cavity at a volume of 3–5 mL/kg using a 50-mL syringe. The catheter was then removed, and the puncture site was sealed with adhesive tape.

Rib fracture model (n = 9): Beagles were intravenously anesthetized with propofol (6–8 mg/kg) and underwent endotracheal intubation, with anesthesia maintained using 1.5%–2.5% isoflurane. Vital signs, including heart rate, blood pressure, respiratory rate, oxygen saturation, ECG, and body temperature, were continuously monitored. Butorphanol (0.2–0.4 mg/kg) was administered for perioperative analgesia. The animals were placed in the left lateral decubitus position. The right chest wall was disinfected with povidone-iodine. At approximately 10 cm from the sternal end of the 5th intercostal space, the 4th, 5th, and 6th ribs were transected. Before closing the chest, residual air was evacuated from the right pleural cavity to prevent iatrogenic pneumothorax.

Humane end points

The following humane end points were pre-established: (1) severe respiratory distress (respiratory rate > 60 breaths/minute or cyanosis); (2) uncontrolled persistent bleeding; (3) inability to stand or cessation of spontaneous eating and drinking within 24 hours; and (4) body weight loss exceeding 20%. If any of these end points occurred, the animal was immediately euthanized by an overdose of sodium pentobarbital (100 mg/kg, intravenous injection).

Initially, a total of 27 beagles were included in the experiment, and by the end of the study, 21 animals were successfully modeled. The exclusions were as follows: in the pneumothorax group, two beagles were excluded due to incomplete imaging data; in the pleural effusion group, one beagle died from an anesthetic accident, and one was excluded due to incomplete data; in the rib fracture group, one beagle was excluded due to postoperative wound infection, and one died from an anesthetic accident (Figure 1).

X-ray examination

All beagles underwent conventional chest X-ray, mobile DR, and portable handheld DR examinations.

Conventional chest X-ray was performed using a F51-5C Medical diagnostic X-ray machine (Wandong, Beijing, China) at 66 kV, 200 mA, with a single exposure time of 0.03 seconds. Mobile DR (DRX-Rise) was performed at 85 kV, 320 mA, with an exposure time of 0.02 seconds. Portable handheld DR (70 kV, 2 mA) was performed with a single exposure time of 0.2 seconds; the device weighed ≤ 2.5 kg (Figure 2). All images were acquired in a standard posteroanterior projection during end-inspiration, with the focal distance set at 150 cm for conventional chest X-ray and mobile DR and at 100 cm for handheld DR. To ensure model stability, the interval between each examination was controlled within 5 minutes.

In strict accordance with standard X-ray examination protocols, conventional posteroanterior projections of the thoracoabdominal region were obtained for all beagles. Following image acquisition, all radiographs were independently reviewed by at least two senior radiologists who were blinded to the imaging modality to avoid observer bias. The reading sequence was randomized for each radiologist, and the two radiologists reviewed the images independently without any communication or mutual influence to ensure the independence of the reading process. To assess interobserver consistency, the kappa (κ) statistic was used: a κ value > 0.75 indicated excellent consistency, 0.40–0.75 indicated moderate to good consistency, and < 0.40 indicated poor consistency. A final diagnosis was established upon consensus between the two radiologists. In cases of discrepancy, a third senior radiologist was invited to review the images jointly to reach a final consensus.

Observation indicators

Detection rates

Imaging data from all animals were collected and independently reviewed by two senior radiologists using a double-blind method. Using surgical findings as the gold standard, the number of true-positive detections for each of the three examination methods was recorded, and the detection rate was calculated as follows: detection rate = (number of positive detections/ total number of cases) × 100%. In cases of disagreement between the two radiologists regarding interpretation, a consensus was reached through group discussion to ensure the accuracy and objectivity of the statistical results.

Grading evaluation of image quality

The evaluation criteria were as follows: Grade A (fully met diagnostic requirements, correct positioning, clear image with optimal contrast, and free from blurring or artifacts); Grade B (met diagnostic requirements, correct positioning, relatively clear image, with minimal blurring or artifacts); Grade C (basically met diagnostic requirements, suboptimal positioning, moderate image clarity and discernibility, with noticeable blurring, artifacts, or noise); non-diagnostic (did not meet diagnostic requirements, poor positioning, severely blurred image, with significant artifacts or noise). The same two radiologists independently graded all images based on these criteria. The proportions of Grade A, Grade B, Grade C, and non-diagnostic images for each of the three examination methods were calculated to compare imaging quality differences across the different devices.

Examination times

The examination times for the three methods were recorded and compared. Examination time was defined as the entire process from the start of animal positioning to the completion of image acquisition and confirmation that the images met diagnostic quality standards. By analyzing and comparing differences in operational efficiency among the three devices, their applicability in emergency or bedside settings was evaluated.

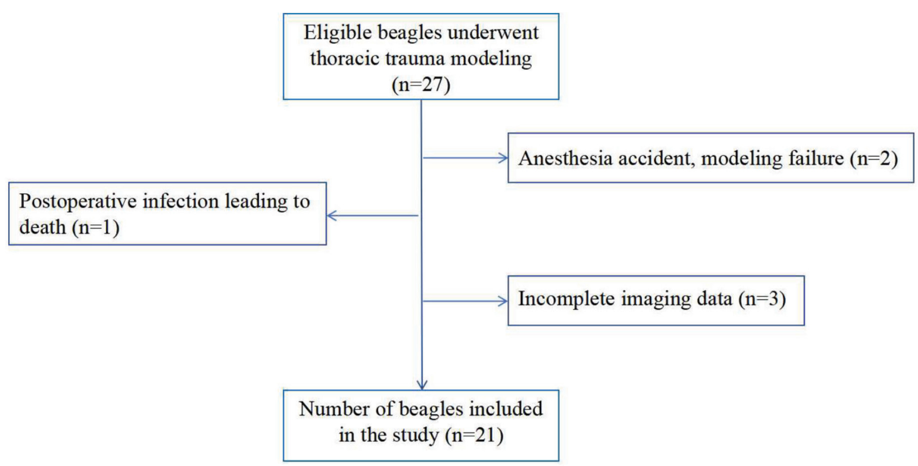

Figure 1. Animal model establishment.

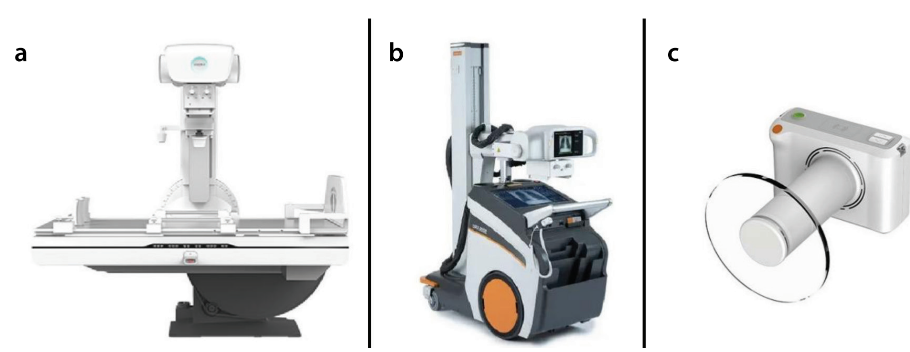

Figure 2. Imaging of devices: conventional chest X-ray device **(a)**, mobile DR **(b)**, and a portable handheld DR **(c)**. DR, digital radiography.

Statistical analysis

Statistical analysis was performed using SPSS version 26.0. Count data were presented as frequencies and percentages [n (%)] and analyzed using Cochran's Q test. Ranked data were assessed using the nonparametric Friedman test. Measurement data were expressed as mean ± standard deviation and analyzed using repeated-measures analysis of variance, with post-hoc pairwise comparisons conducted using the least significant difference t-test. A value of $P < 0.05$ was considered statistically significant.

Results

Detection rates of thoracic trauma

The detection rates for thoracic trauma varied across the three examination methods (Table 1). Mobile DR demonstrated the highest detection rate at 85.71%, followed by portable handheld DR (80.95%) and conventional chest X-ray (66.67%). However, despite the apparent numerical advantage of the mobile and portable handheld DR methods, the differences among the three groups did not reach statistical significance ($P > 0.05$). This suggests that although portable handheld DR may offer comparable diagnostic performance, the current sample size may be insufficient to detect a true difference.

Image quality assessment

Image quality grades for the three examination methods are presented in Table 2. Both mobile DR and portable handheld DR demonstrated significantly higher image quality than conventional chest X-ray. The differences were statistically significant ($P < 0.05$, Table 2). However, the difference in image quality between mobile DR and portable handheld DR was not statistically significant ($P > 0.05$), indicating that both mobile DR and portable handheld DR provided comparable image quality that was superior to conventional chest X-ray.

Examination time

The total examination times for the three examination methods are presented in Table 3. Conventional chest X-ray had the longest examination time (10.40 ± 0.96 minutes), followed by mobile DR (8.37 ± 0.80 minutes), whereas portable handheld DR was the fastest (7.07 ± 0.67 minutes). The overall differences among the three methods were highly significant ($P < 0.001$). Pairwise comparisons revealed that both mobile DR and portable handheld DR significantly reduced examination time compared with conventional chest X-ray ($P < 0.05$). Furthermore, portable handheld DR was significantly faster than mobile DR ($P < 0.05$).

Discussion

In this study, the fracture detection rate of portable handheld DR showed no statistically significant difference compared with conventional chest X-ray or mobile DR, and its image quality was comparable to that of conventional DR ($P > 0.05$). However, it demonstrated a significantly faster examination speed. Acute thoracic trauma is often more complex, progresses more rapidly, and is more difficult to diagnose than ordinary trauma, necessitating accurate and efficient diagnostic tools. The resulting critical conditions are frequently life-threatening, and delayed diagnosis and treatment may lead to death from hemorrhagic shock or respiratory failure within a short period.[5] DR technology enables rapid acquisition of high-resolution images without requiring special patient cooperation. Its simple workflow, low radiation dose, and ease of storage substantially streamline emergency care and save valuable time for patient management.

Previous studies have shown that portable handheld DR devices could be used for tuberculosis screening, with image quality comparable with that of digital X-ray machines commonly used in medical facilities. Moreover, portable handheld DR devices were easy to operate and could be transported to any location.[4] Chest X-rays obtained using camera-type portable X-ray devices could be used for clinical evaluation of indwelling instruments.[6] Due to their high mobility and operational simplicity, portable DR devices enable rapid diagnosis in challenging conditions. Their outstanding emergency response capability makes them the preferred imaging modalities for military and disaster rescue scenarios.[7] The present study found no significant difference between portable handheld DR and mobile DR in terms

Table 1. Comparison of detection rates among the three examination methods

Method	Conventional X-ray	Mobile DR	Portable handheld DR	Q	*P*
Pneumothorax (n = 7)	5	6	5	1.000	0.607
Pleural effusion (n = 7)	5	6	6	0.500	0.779
Rib fracture (n = 7)	4	6	6	2.000	0.368
Missed diagnosis	7	3	4		
Positive detection rate [% (n/m)]	66.67% (14/21)	85.71% (18/21)	80.95% (17/21)	2.600	0.273
95% CI	(0.447, 0.887)	(0.694, 1.020)	(0.626, 0.810)		

DR, digital radiography; CI, confidence interval.

Table 2. Comparison of the image quality of the three examination methods

Method	Grade A	Grade B	Grade C	Non-diagnostic	95% CI
Conventional X-ray	14	5	2	0	(1.12, 1.74)
Mobile DR	20	1	0	0	(0.95, 1.15)
Portable handheld DR	19	2	0	0	(0.96, 1.23)
χ^2	7.750				
P	0.021				

DR, digital radiography; CI, confidence interval.

Table 3. Comparison of examination times among the three examination methods

Method	Examination time (min)	95% CI
Conventional X-ray	10.40 ± 0.96	(9.968, 10.845)
Mobile DR	8.37 ± 0.80[a]	(8.008, 8.737)
Portable handheld DR	7.07 ± 0.67[ab]	(6.771, 7.378)
F	89.367	
P	<0.001	

[a]$P < 0.05$ vs. conventional X-ray; [b]$P < 0.05$ vs. mobile DR. DR, digital radiography; CI, confidence interval.

of fracture detection rate and image quality. Research by Audin et al.[8] also confirmed that wireless portable DR can provide clinical information equivalent or superior to computed radiography in bedside chest radiography in the intensive care unit (ICU). Furthermore, the latest portable dynamic DR technology has expanded the functional applications of bedside chest imaging, offering new tools for the rapid assessment of trauma patients.[9] Collectively, these studies support the clinical value of portable DR in the diagnosis of thoracic trauma, particularly its advantages in specialized settings such as emergency departments, ICUs, and disaster sites. The device features an integrated design with low radiation dose (leakage ≤ 2.4 μGy/hour at 1 minute), high safety, lightweight construction, and palm-sized operability, providing reliable imaging support for emergency scenarios.

This study has several limitations. First, the diagnostic value of portable handheld DR was investigated only in a beagle animal model, and no human clinical studies have been conducted, which limits the generalizability of the results to clinical practice. In addition, the long-term stability and practicality of the device in extreme environments, complex trauma types, and mass-casualty scenarios have not been thoroughly evaluated. Further validation through large-sample, multicenter clinical studies is warranted.

Conclusion

In summary, portable handheld DR offers simple operation and high portability, enabling rapid deployment in complex emergency settings. While ensuring safety and diagnostic efficacy, it can meet basic imaging needs in first-aid scenarios. Its significant application potential in environments lacking fixed equipment, such as disaster relief sites and field medical rescue operations, provides crucial support for optimizing imaging equipment allocation and emergency procedures in these contexts.

Footnotes

Conflict of interest disclosure

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References

1. Dogrul BN, Kiliccalan I, Asci ES, Peker SC. Blunt trauma related chest wall and pulmonary injuries: an overview. *Chin J Traumatol*. 2020;23(3):125-138. [Crossref]
2. Lodhia JV, Eyre L, Smith M, Toth L, Troxler M, Milton RS. Management of thoracic trauma. *Anaesthesia*. 2023;78(2):225-235. [Crossref]
3. Zhang ZL. Analysis and research on the role and value of DR in the diagnosis of rib fractures. Chin Med Device Inform. 2023;29:110-112. [Crossref]
4. Kamal R, Singh M, Roy S, et al. A comparison of the quality of images of chest X-ray between handheld portable digital X-ray & routinely used digital X-ray machine. *Indian J Med Res*. 2023;157(2&3):204-210. [Crossref]
5. Yahyoev SMO, Khodzhimatov GM. Diagnostic methods and surgical treatment of patients with thoracoabdominal traumas (review of the literature). *Kardiochir Torakochirurgia Pol*. 2022;19(4):226-231. [Crossref]
6. Kim SJ, Yong HS, Kang EY, Yang Z, Kim JY, Yoon YH. Is a camera-type portable X-Ray device clinically feasible in chest imaging?: Image quality comparison with chest radiographs taken with traditional mobile digital X-Ray devices. *J Korean Soc Radiol*. 2024;85(1):138-146. [Crossref]
7. Ma X, Zhang B, Qi Z, et al. Applicability of field portable digital radiology on the plateau. *Aviation Medicine of Air Force*. 2022;39(2):179-180. [Crossref]
8. Audin CR, Aran S, Muse VV, et al. Bedside chest radiographs in the intensive care setting: wireless direct radiography compared to computed radiography. *Curr Probl Diagn Radiol*. 2018;47(6):397-403. [Crossref]
9. Cè M, Oliva G, Rabaiotti FL, et al. Portable dynamic chest radiography: literature review and potential bedside applications. *Med Sci (Basel)*. 2024;12(1):10. [Crossref]