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Reducing Missed Fractures

Radiobotics' RBfracture™ at Kettering General Hospital

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Introduction

Kettering General Hospital (KGH) recently completed a pilot evaluation to assess the AI fracture detection tool, RBfracture™. The aim was to reduce missed fracture rates in the hospital's Accident and Emergency (A&E) department, especially in the out-of-hours, where acute musculoskeletal exams are not immediately reported by radiologists or reporting radiographers. With thousands of patients visiting A&E annually, many undergo plain-film (X-ray) examinations to diagnose fractures and trauma. However, the high volume of cases, staff turnover, and resource constraints can lead to diagnostic errors, resulting in increased wait times, treatment delays, and negative patient outcomes. One of the most common diagnostic errors encountered is the missed fracture [1].

Recent research has demonstrated that AI algorithms designed for the detection of fractures are not only on par with human capabilities but often surpass the performance of non-expert human readers [2]. Integrating AI as a decision-support tool for fracture detection holds significant promise in enhancing the diagnostic accuracy of both experienced medical professionals and those with limited expertise in this domain.

FACT BOX RBfracture

RBfracture is a clinical decision support tool to identify fractures and related findings in X-ray radiographs (XRs) in patients above the age of 2 years. RBfracture has been trained on a representative dataset of XRs from more than 100,000 patients. It seamlessly integrates with the hospital's IT infrastructure, providing instant findings via output image with bounding boxes to clinicians within their normal PACS software.

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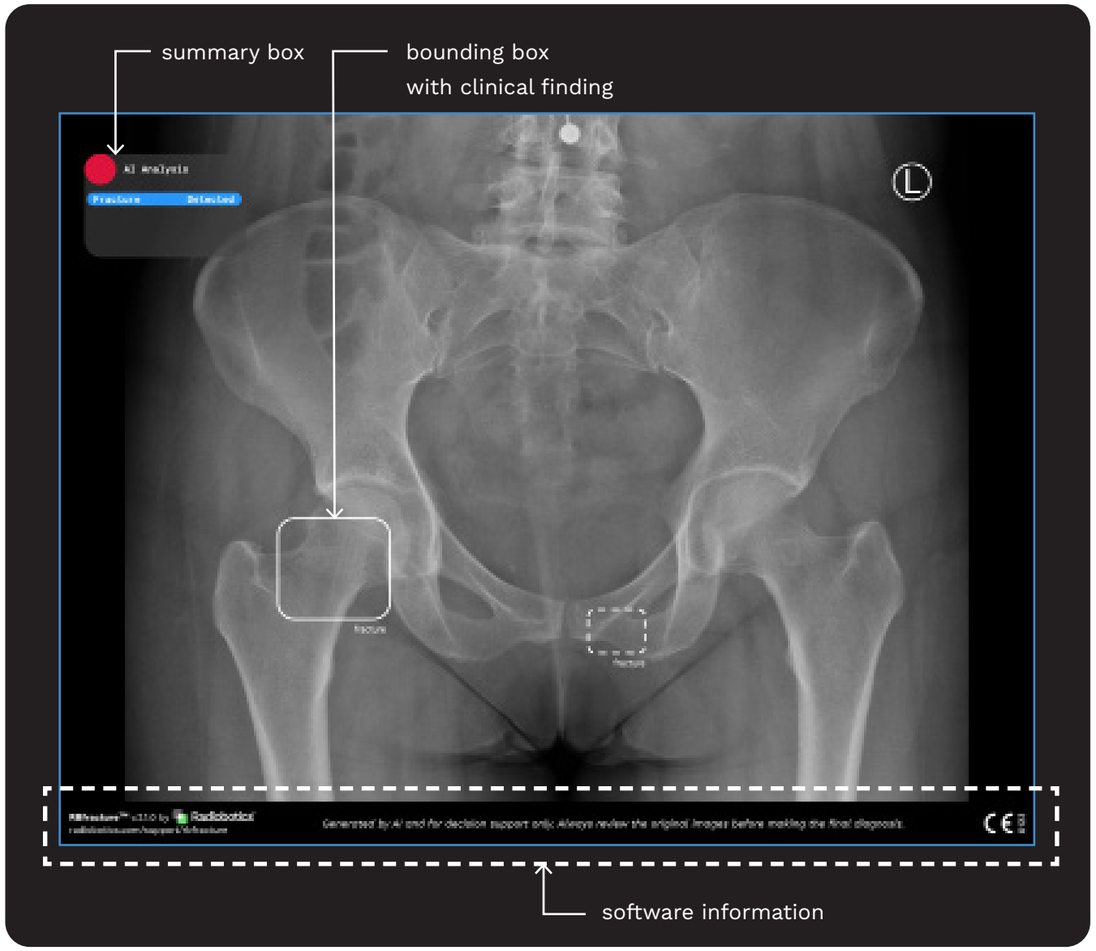
RBfracture™

Images below are examples only.

Annotated Radiograph



Important! Generated by AI and for decision support only.
Always review the original images before making the final diagnosis.

Figure 1. RBfracture™

Method

The pilot aimed to measure the impact of RBfracture in an NHS setting. RBfracture was seamlessly integrated into the diagnostic workflow utilising Radiobotics' cloud (Microsoft Azure, UK South, London) and output was reviewed within KGH's existing clinical systems. See Figure 2 and Fact Box for an overview of RBfracture. The assessment of RBfracture involved a retrospective audit of the algorithm's standalone performance and a prospective analysis of missed fracture rates.

RBfracture Standalone Performance

RBfracture's performance was assessed by calculating accuracy, sensitivity (true positive rate) and specificity (true negative rate) on a dataset of 319 cases selected by KGH. The Reporting Radiography team at KGH typically reviews MSK XR cases from A&E within 24 hours of acquisition. Consecutive radiographs from 16 random days in November '23 through January '24 were used for the audit. Two Reporting Radiographers independently reviewed the radiographs, and their consensus served as the reference standard ("'gold standard") for RBfracture. In cases of disagreement, a third reviewer was consulted.

Missed Fracture Rate

Missed fracture incidents are flagged retrospectively when the initial interpretation made by the A&E staff is compared to the official radiology report. If the discrepancy is significant, the patient may need to be recalled for further examination. Evaluation of missed fractures at KGH are done continuously on a day-to-day basis.
For the purpose of this pilot, the number of missed fractures were aggregated over the period from January through June and July through December, respectively. The number of incidents of this nature when using RBfracture was compared to a historical baseline obtained from the same period in the previous years and indicate the change in missed fracture rates.

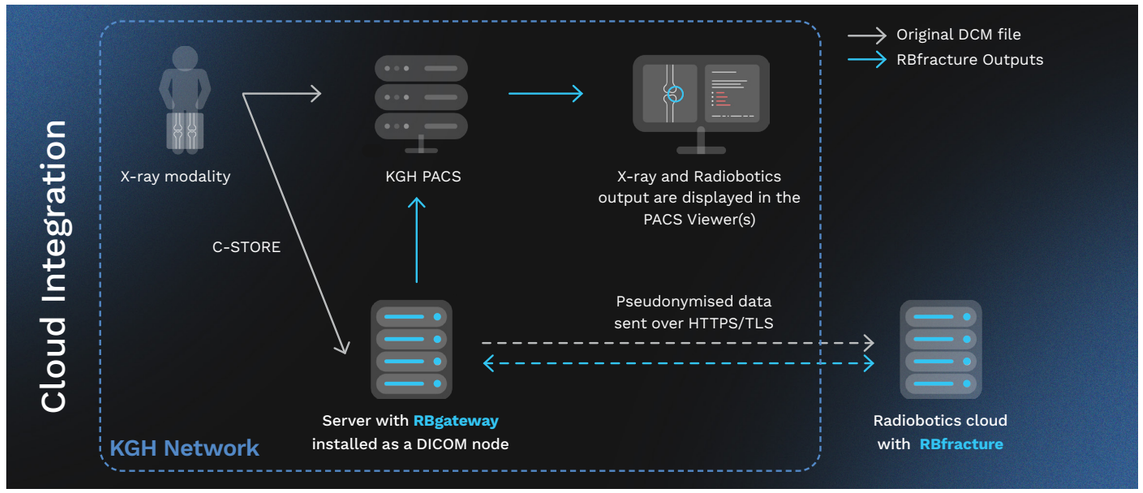


Figure 2. RBfracture cloud integration at Kettering General Hospital (KGH)

FACT BOX Integration

RBfracture was deployed such that all acute XR exams acquired in the A&E department were automatically forwarded to a gateway installed locally at the KGH premises. From the gateway, the XRs were pseudonymised and forwarded to the Radiobotics cloud over a secure connection. Results were returned via the gateway to the KGH Picture Archiving and Communication System (PACS) and stored in the same exam as the original XRs. All connections to Radiobotics' cloud are encrypted using the HTTPS protocol.

WHAT ARE THE BENEFITS OF **CLOUD INTEGRATION**?

Automatic Updates

Cloud-based applications receive automatic updates, ensuring users always have access to the latest features and improvements without the need for manual installation.

Cost Efficiency

Cloud installations typically operate on a pay-as-you-go pricing model, which can reduce capital expenditure and eliminate the cost of maintaining and updating physical hardware.

Regular Security Updates

Cloud installations are regularly updated to address new security threats, with patches and updates applied automatically to protect against vulnerabilities.

Proof-of-concept timeline

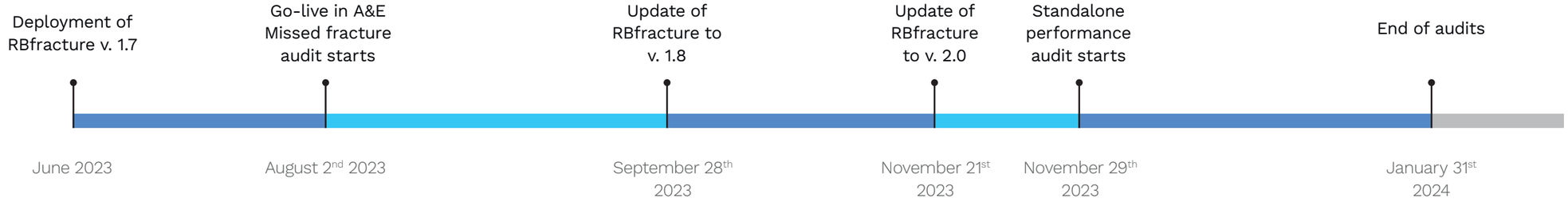


Figure 3. The deployment of RBfracture v. 1.7 was made in the June 2023 and clinical go-live date was August 2nd 2023. RBfracture was updated to version 1.8 on September 22nd 2023 and to version 2.0 on November 21st 2023. Fracture audit for standalone performance evaluation was performed from November 28th 2023 through January 2024.

Results: Benefit to the Organisation and Patients

A total number of 14,791 patient exams were processed during the pilot period. 16% of cases were below the age of 18. The median processing time of each exam was 13 seconds and 90% of cases were processed within 23 seconds. These numbers do not take into account the transfer time within the KGH network.

RBfracture Standalone Performance

A total of 319 patient exams were included in the audit of the RBfracture standalone performance. The distribution between anatomical regions is shown in Table 1. At least one fracture was present in 78/319 (24%) of the cases. A confusion matrix with the fracture status and predictions made by RBfracture is shown in Table 2. The sensitivity was 94%, specificity was 94%, and accuracy was 94%. The negative predictive value (NPV) was 98% and the positive predictive value (PPV) was 83%. The agreement between reporters was 96%. The median (minimum, maximum) patient age was 52 (2, 94) years, with the Hip/Pelvis being the most frequently examined body part.

Table 1. Exams included in standalone performance audit

Body Part	Number (percentage)	Fracture prevalence
Finger	11 (3%)	27%
Hand	34 (11%)	26%
Wrist	29 (9%)	24%
Forearm	10 (3%)	40%
Elbow	11 (3%)	27%
Humerus	8 (3%)	38%
Shoulder	38 (12%)	39%
Clavicle	3 (1%)	33%
Toe	3 (1%)	0%
Foot	26 (8%)	35%
Ankle	32 (10%)	16%
Tibia/Fibula	8 (3%)	25%
Knee	43 (13%)	12%
Femur	6 (2%)	17%
Hip/Pelvis	57 (18%)	19%
Total	**319 (100%)**	**24%**

Table 2. Confusion matrix with derived performance measures

		RBfracture diagnosis: Positive	RBfracture diagnosis: Negative	
True diagnosis	Positive	TP = 73	FN = 5	**Sensitivity = 94%**
	Negative	FP = 15	TN = 226	**Specificity = 94%**
		PPV = 83%	NPV = 98%	**Accuracy = 94%**

Abbreviations:
True-Positive (TP), True-Negative (TN), False-Positive (FP), False-Negative (FN), Positive Predictive Value (PPV), Negative Predictive Value (NPV)

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Missed Fracture Rate

Prior to the introduction of RBfracture, the missed fracture rate ranged between 1.9 to 4.5 per 1000 examined patients. Following its introduction in August 2023 and through January 2024, 15 cases of missed fractures were reported, equivalent to a missed fracture rate of 1.0 per 1000 patients. See Figure 4. This represents a 47%-62% reduction in missed fracture rate when compared to the second half of 2021 and 2022, respectively. Of the recorded 15 missed cases, 8 were indicated up by RBfracture, but still missed by the A&E, 2 occurred during downtime, and 5 were deemed a false negative by both A&E and RBfracture. See Figure 5.

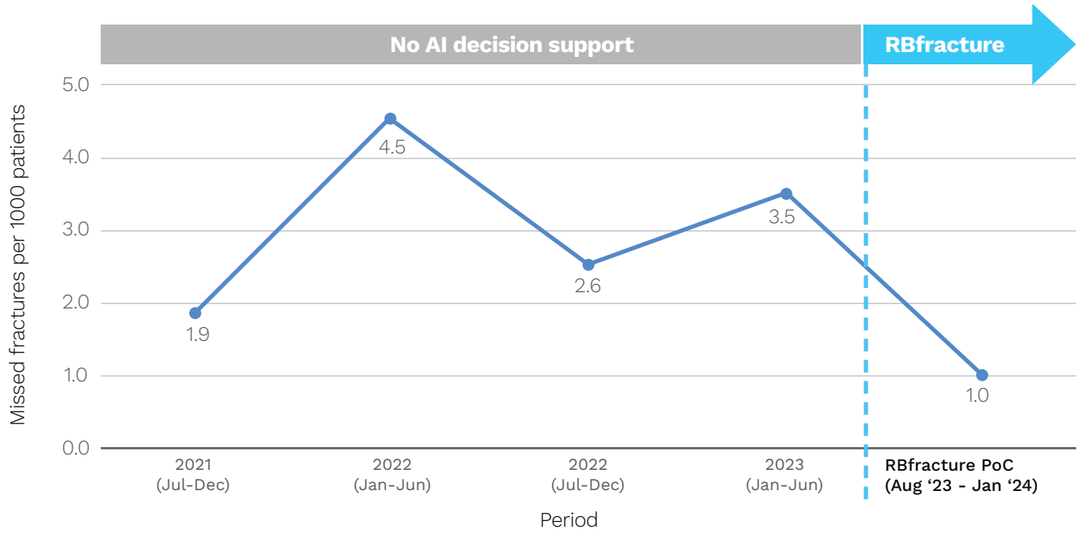

Figure 4. Missed fractures in the Accident and Emergency department at Kettering General Hospital before and after introduction of RBfracture.

Missed fractures during RBfracture Proof-of-Concept period

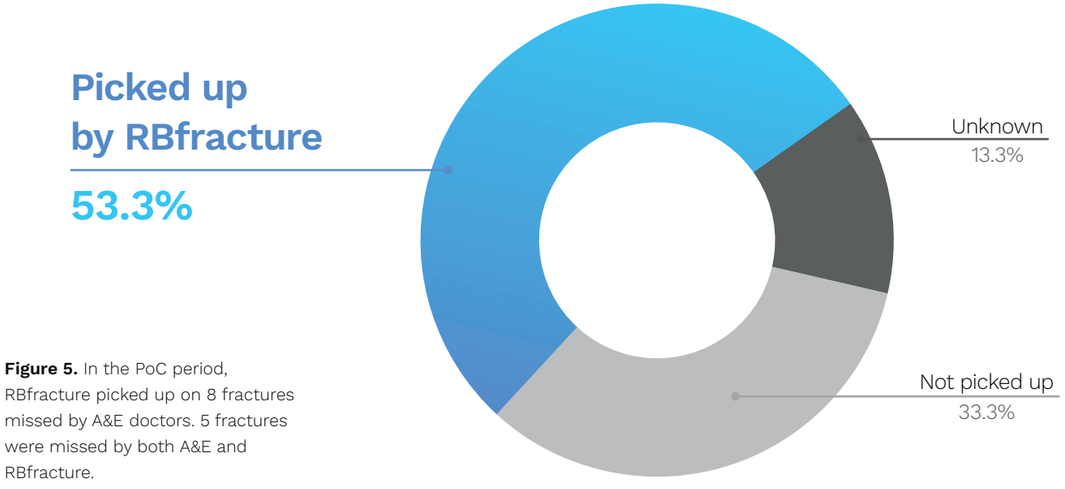

Figure 5. In the PoC period, RBfracture picked up on 8 fractures missed by A&E doctors. 5 fractures were missed by both A&E and RBfracture.

Perspectives

The deployment of RBfracture at Kettering General Hospital has improved the initial assessment of X-rays. It has enhanced medical professionals' performance, resulting in quantifiable benefits such as a significant decrease in missed fracture rates. This improvement translates to better patient outcomes, reducing the likelihood of incorrect discharge and subsequent readmission, thus alleviating both cost and care burdens.

"Hot-reporting" where acute musculoskeletal radiographic exams are reported immediately by reporting radiographers in the emergency department (ED) has been shown as a cost-effective alternative to the delayed radiology reporting (usually the following day) of ED exams with average cost-saving of £23.40 per patient [3]. A comparable saving could be speculated when using RBfracture as an immediate reporter, without the need for a 24-hour radiology reporting service.

Given the hospital's substantial volume of hip/pelvic exams in individuals over 50, swift identification of fractures is crucial. A recent retrospective observational study demonstrated a direct correlation between a surgical delay of more than 12 hours and the increased adjusted risk of 30-day mortality. Additionally, it demonstrated a surgical delay of more than 24 hours significantly increased the adjusted risk of 90-day mortality [4].

Furthermore, current guidelines from National Institute of Health and Care Excellence (NICE) recommend that a radiologist, reporting radiographer or other trained reporter should deliver the definitive written report of emergency department X-rays of suspected fractures before the patient is discharged from the emergency department [5]. This requires a 24-hour reporting service, that is not readily available at all acute NHS trusts and a solution like RBfracture could bridge this gap for trusts without radiology staff available 24/7.

FACT BOX The POC at KGH will continue with objectives including...

Reducing errors in diagnosis

RBfracture is designed to augment human interpretation of X-rays which results in greater sensitivity to fracture detection.

Reduce time to diagnosis

Increasing sensitivity at the point of X-ray reduces the requirement for additional supplementary scans and reduces time to treatment for patients.

Streamline referrals to fracture clinics

Increasing diagnostic accuracy at the point of X-ray reduces the number of inappropriate referrals to fracture clinics.

Increase confidence in staff

The adoption of RBfracture will enhance the confidence of medical staff by offering dependable support in the diagnostic process, instilling greater assurance in their decisions.

References

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This paper was reviewed and approved by Ben Madden, Lead Reporting Radiographer at Kettering General Hospital, who was responsible for implementation and for conducting the RBfracture audit. Ben Madden declares no conflict of interest.