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Original article

Impact of introducing extremity cone-beam CT in an emergency radiology department: a population-based study.

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Abstract

Background

Musculoskeletal cone-beam CT (CBCT) recently appeared on the market, with image quality comparable to that of high-resolution CT. It was previously implemented mainly in craniofacial surgery and in orthopedic limb surgery for weight-bearing imaging, but without large-scale assessment in emergency settings. We therefore conducted a retrospective comparative study in an emergency radiology department: 1) to assess whether introduction of CBCT dedicated to extremity traumatology reduced radiation dose delivered to the patient undergoing cross-sectional imaging, 2) to assess whether it increased turnover, and 3) to study the feasibility and practical consequences.

Study hypothesis

Introducing CBCT dedicated to traumatology in an emergency radiology department reduces radiation dose related to cross-sectional imaging in extremity trauma.

Patients and methods

Two periods were distinguished: in May-November 2016, the only cross-sectional imaging available in our emergency radiology department was multi-detector CT (MDCT); in May-November 2017, both MDCT and CBCT were available. Thus, the population in period 1 (n=165) had undergone only MDCT extremity imaging, while patients in period 2 underwent either CBCT (n=139) or MDCT (n=85). Study parameters notably included dose-length product (DLP) and length of patient stay in the radiology department (turnover).

Results

Mean DLP was significantly reduced with the introduction of CBCT: 210.3 ± 133.6 mGy.cm (range, 20-595) in period 1, versus 138.4 ± 92.7 mGy.cm (range, 32-623) in period 2 ($p < 0.0001$). Taking both periods together, mean DLP was 50.7% lower with CBCT (n=139) than MDCT (n=249): respectively, 101.6 ± 14.9 mGy.cm (range, 50.6-126.9) versus 206.5 ± 131.8 mGy.cm (range, 20-623) ($p < 0.0001$).

Turnover accelerated with the introduction of CBCT, with mean stay of 84.9 minutes in period 1 versus 72.1 minutes in period 2 ($p=0.011$). In period 2, turnover was 23.6% faster with CBCT than MDCT: respectively, 64.9 minutes versus 85.0 minutes ($p=0.0004$).

Discussion

Introducing CBCT dedicated to the extremities in an emergency radiology department was feasible. It reduced overall radiation dose and accelerated turnover.

Level of Evidence: III; comparative case-control study.

Key Words: Cone-beam Computed Tomography; Multidetector Computed Tomography; Bone fractures; Radiology; Emergency department.

1. Introduction

Cone-Beam CT (CBCT) is a recent advance in radiology, widely used in craniofacial and dental imaging [1-3]. Using a conical X-ray beam, it provides submillimetric 3D imaging, that moreover is isotropic. The X-ray source rotates once around the target. The device comprises a flat-panel detector rather than the multiple rows of conventional multi-detector CT (MDCT) [1–3]. More recently, devices devoted to musculoskeletal imaging, notably of the extremities, have appeared on the market and obtained authorization for clinical use from the American FDA (Food and Drug Administration) and the EU with CE labeling [4,5]. Some enable weight-bearing imaging, notably of the foot and ankle, which was one of the first reported fields of application in orthopedics [6,7]. In terms of image quality, several studies demonstrated that CBCT shows spatial resolution and contrast comparable to high-resolution MDCT [8–12] (Figure 1). In terms of radiation dose, current data suggest a 2-to-7-fold reduction compared to MDCT [13–18], but most studies used small samples, cadavers or phantoms, with no large-scale assessments in current care.

A few studies focused on CBCT in extremity trauma [9,19]. Although sample sizes were small, initial results indicated excellent performance in diagnosing traumatic bone lesions, opening up new avenues of clinical application [20,21]. To supplement these preliminary findings, we conducted a retrospective comparative study in a large population of patients undergoing MDCT or CBCT for extremity trauma in an emergency radiology department, under routine clinical conditions, with the aim of assessing: 1) whether the introduction of extremity CBCT reduced radiation dose in patients undergoing imaging; 2) whether it increased patient turnover; and 3) the feasibility and practical consequences. The study hypothesis was that introducing extremity CBCT in an emergency radiology department reduces related radiation dose in imaging for extremity trauma.

2. Patients and Methods

2.1 Patients and examinations

A CBCT scanner dedicated to the extremities (OnSight 3D, Carestream Health, Rochester, NY, USA) was available in the emergency radiology department of the University Hospital of Lille (France) from May to November 2017. The department performs 18,000 to 20,000 musculoskeletal radiographs a year in patients referred from the Emergency Department for recent trauma. On weekdays, radiographs are immediately interpreted by a senior radiologist specializing in musculoskeletal imaging. The radiologist also performs targeted clinical examination and, if needed, completes the radiographic work-up with supplementary views or other examinations such as ultrasound or CT. After such complete assessment, a report is drawn up and the patient is referred back to Emergency Department for subsequent treatment.

In the present study, two periods were distinguished. In period 1, from May to November 2016, the only cross-sectional imaging available for traumatology was conventional MDCT (Siemens Somatom Definition AS, Siemens Healthcare GmbH, Erlangen, Germany), using routine parameters: 120 kV; 220–250 mAs; slice thickness: 0.4 mm (in ultra-high resolution (zUHR), which is more irradiating but gives better bone image quality) or 0.6 mm (in standard resolution (SR)). In period 2, from May to December 2017, two modalities were available: MDCT, with the same parameters, or CBCT, with the manufacturer's default parameters: 80-90 kV; 3.8-5.6 mAs; slice thickness: 0.26 mm. Choice between the two was at the radiologist's discretion for each patient.

All consecutive trauma patients undergoing routine MDCT or CBCT of the extremities as described above for the 2 periods were included. MDCT performed at night or weekends were not included, as the organization was different: on-call radiologists not systematically specialized in musculoskeletal imaging; different priority for multi-organ emergency MDCT; no CBCT available. As CBCT allowed only examination of extremities (foot and ankle, knee, hand and wrist, elbow), only MDCT scans of these regions were included for comparison.

2.2 Methods

Anonymized data were collected and analyzed retrospectively after the end of period 2, in conformity with the General Data Protection Regulations (GDPR) and approval from the institution's Data Protection Officer (n° DEC-18-337). Scans meeting the inclusion criteria were extracted from the institution's PACS (Picture Archiving and Communication System: IntelliSpace PACS, Koninklijke Philips, Eindhoven, Netherlands). Patient age and body region were collected. Dose-length product (DLP) and resolution (zUHR or SR in MDCT) were extracted from the scan radiation report. Scans were classified by a radiologist specializing in musculoskeletal imaging as positive (post-traumatic abnormalities) or negative (normal or non-traumatic abnormalities). Turnover was assessed as length of stay in the emergency radiology department: time of first radiograph to time of report validation. Patients with radiographs taken elsewhere were excluded from turnover analysis (6 in period 1, 3 in period 2).

2.3 Statistics

Statistical analysis used Prism software, v8 (GraphPad Software, La Jolla, CA, USA). Quantitative variables were reported as mean \pm SD. Paired quantitative variables were compared on Kolmogorov-Smirnov test; comparison between ≥ 3 quantitative variables used Kruskal-Wallis test and post-hoc Dunn test. Qualitative variables were reported as number and percentage and compared on chi² test. The significance thresholds were $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***), and $p < 0.0001$ (****).

3. Results

In period 1, 5,067 patients referred from Emergency underwent radiography of one or more extremities. One hundred and Sixty-six (3.28%) underwent complementary cross-sectional imaging matching the inclusion criteria (all, by definition, MDCT). In period 2, 224 out of 5,530 patients (4.05%) underwent complementary cross-sectional imaging matching the inclusion criteria (85 MDCT, 139 CBCT): i.e., a significant increase in the rate of complementary cross-sectional imaging ($p=0.034$).

Mean DLP in period 1 was 210.3 ± 133.6 mGy.cm (range, 20-575), versus 138.4 ± 92.66 mGy.cm (range, 32-591) in period 2: i.e., a reduction of 34.2% after introduction of a CBCT in the radiology department ($p < 0.0001$) (Figure 2). Taking both periods together, 249 MDCT scans were performed: 150 zUHR and 99 SR. Mean DLP in CBCT was 101.6 ± 14.9 mGy.cm (range, 50.6-126.9), significantly lower than in MDCT ($n=249$; 206.5 ± 131.8 mGy.cm (range, 20-623)) ($p < 0.0001$), for an overall decrease of 50.7% (Figure 3). Mean DLP in CBCT (101.6 ± 14.9 mGy.cm; $n=139$) was comparable to SR MDCT (104.4 ± 95 mGy.cm; $n=99$) ($p > 0.99$) but significantly lower than in zUHR MDCT (274.0 ± 107.1 mGy.cm; $n=150$) ($p < 0.0001$): i.e., a decrease of 62.9% (Figure 3), with comparable image quality. Table 1 and Figure 4 show dose per subgroup per joint.

Mean stay in period 2 (72.1 ± 34 min; range, 13-222) was significantly shorter than in period 1 (84.9 ± 43 min; range, 21-250) ($p=0.011$) (Figure 5), and significantly shorter in CBCT (64.9 ± 29 min; range, 13-222) than MDCT (85.0 ± 39 min; range, 34-203) in period 2 ($p=0.0004$): i.e., a 23.6% increase in turnover.

Mean age was 41.8 ± 18.3 years (range, 10.3-91.7) in period 1 ($n=166$) and 39.6 ± 20.6 years (range, 6-95.8) in period 2 ($n=224$) (NS: $p=0.096$). In period 2, patients undergoing CBCT had lower mean age than with MDCT: 35.4 ± 18.2 years (range, 6-90) versus 46.6 ± 22.5 years (range, 10.4-95.8), respectively ($p=0.003$). In period 1, 65 examinations were foot/ankle (39.2%), 16 knee (9.6%), 28 elbow (16.9%) and 57 wrist/hand (34.3%), and in period 2 respectively 90 (40.2%), 39 (17.4%), 26 (11.6%) and 69 (30.8%) (NS: $p=0.094$). In period 2, joints explored differed between CBCT and MDCT ($p=0.011$), with 63 CBCT foot/ankle scans (63/90, 70%) versus 27 on MDCT (27/90, 30%); likewise there were 16 CBCT hand/wrist scans (46/69, 66.7%) versus 23 on MDCT (23/69, 33.3%).

The proportion of scans showing traumatic abnormalities was stable between periods 1 and 2: respectively, 119 (119/166, 71.7%) and 153 (153/224, 68.3%) positive examinations ($p=0.47$). In period 2, the rate of positive examinations did not significantly differ between CBCT (96/139, 69.1%) and MDCT (57/85, 67.1%) ($p=0.75$).

In period 2 overall, the two techniques were used equally: 51% CBCT, 49% MDCT ($p=0.78$). Use of CBCT, however, progressed significantly to 72% at end of period 2, up from 28% ($p<0.0001$); CBCT became the method of choice.

4. Discussion

The originality of the present study lay in analyzing the practical clinical impact of introducing extremity CBCT in an emergency radiology department. To our knowledge, its sample of patients in current care is the largest on the subject, demonstrating feasibility.

Mean DLP decreased significantly with the introduction of CBCT, indicating that CBCT can help reduce patient irradiation in clinical practice. Moreover, CBCT produces high-resolution images [8–11], with radiation dose 62.9% lower than with MDCT zUHR in the present series, in agreement with previous reports of ex-vivo studies and smaller patient samples [13–17]. DLP is only an indirect index of dose received by the patient, but is widely recognized for dosimetric assessment in CT, as in Diagnostic Reference Levels [22,23]. The volumetric CT Dose Index (CTDI) could also have been used [22,23]. However, as explored length is constant in CBCT (23 cm for the model used in the present study), CTDI, while relevant for joints, such as the knee or elbow, in which explored length is comparable between CBCT and MDCT, tends to overestimate MDCT dose in distal joints, and especially the hands and feet, where explored length in MDCT is usually less than 23 cm. Although the extremities show relatively low radiosensitivity, the ALARA principle, “As Low As Reasonably Achievable”, should always be applied and encouraged, even in emergencies [24].

Turnover for cross-sectional imaging was significantly accelerated in period 2 by the shorter stay required for CBCT. MDCT stay was unchanged between the 2 periods, where practices remained the same. The acceleration was thus thanks to the dedicated supplementary device, whereas MDCT has to be available for emergencies in several specialties. Introducing CBCT met the institution’s need to speed up turnover in the Emergency Department and in traumatology in particular. These

findings agree with a recent study of CBCT in scheduled weight-bearing imaging [25], where its introduction decreased acquisition time by 77% compared to classical radiography and/or MDCT.

In the course of period 2, the radiologists, who were free to choose technique, progressively came to favor CBCT over MDCT, particularly for scans of the ankle, foot, wrist or hand. This may have been due to increasingly easy access to a dedicated device, while MDCT had to be available for emergencies in other specialties. It may also be due to ease of patient positioning in these indications and the high rate of clinical and/or radiographic doubt, such as in scaphoid [19] or Lisfranc joint fracture [26], to avoid overlooking occult fractures while delivering a lower dose, especially to young patients; this may account for the lower mean age in the CBCT population.

The present study did not try to deal with medical economics. CBCT devices are cheaper at purchase than MDCT, but French health budgeting (CCAM: Classification Commune des Actes Médicaux) does not include CBCT scans of the extremities in its reimbursement policy so far, and this lack of cover prevents wider application. In the “general” emergency setting, with devices not specifically dedicated to traumatology, CBCT can easily be integrated in the overall organization, but the present study showed that cross-sectional imaging of the extremities was not sufficiently widely used to amortize such a dedicated device, most diagnoses being still founded on standard X-ray. If CBCT came to be budgeted for, it could replace X-ray for first-line assessment in joints requiring more than two views and subject to frequent false negatives on standard radiography (e.g., tarsal or carpal trauma), to minimize total radiation dose while improving diagnostic performance. This is a hypothetical situation, which could be the focus of future studies.

The main study limitations were due to the single-center retrospective design, with results determined by local practices. The organization described here has been validated for our institution, but may differ between hospitals, notably regarding the availability of radiological resources. The retrospective design precluded precise analysis of why radiologist preferred CBCT over MDCT, as the reason for choice was not entered in the patients’ files. The two devices were set up in adjacent rooms, avoiding the need for specific stretcher transport. Positioning and acquisition

times were comparable in both. One explanation for the radiologists' preference may be the longer wait-time for MDCT, which was also used by other specialties, but this hypothesis could not be reliably tested. However, this does not cast any doubt on the actual findings for the two periods, or on the dosimetric analysis, which was independent of such organizational factors. MDCT scans performed during night-shifts and at weekends were not included, as the organization was different during these times, with no CBCT available as an alternative and longer wait-times due to the needs of other specialties; excluding these scans was thus not a limitation but a means of enhancing inter-group comparability. Lastly, patients underwent only one type of imaging each: CBCT or MDCT; this precluded assessing individual differences in image quality between the two. However, this has been dealt with elsewhere, showing image quality to be very similar in both [8–12].

5. Conclusion

The introduction of dedicated extremity trauma CBCT in the clinical routine of our emergency radiology department was feasible. It decreased overall radiation dose to the patient, and accelerated turnover.

Conflict of interest: Vincent Morel, Julien Dartus, Sammy Badr and Xavier Demondion have no conflicts of interest to disclose in relation to the present study or elsewhere.

Thibaut Jacques was invited by Carestream Health to the European Congress of Radiology (2018) to present the results of this study; Anne Cotten has been a consultant for Bracco Imaging and MSD France.

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Contributions of each author: Thibaut Jacques: Conception and design of the study; acquisition of data; analysis and interpretation of data; manuscript drafting and revision; statistics; final approval. Vincent Morel: Conception and design of the study; analysis and interpretation of data; manuscript drafting and revision; final approval. Julien Dartus: Manuscript revision; final approval. Sammy Badr: Manuscript revision; final approval. Xavier Demondion: Conception and design of the study; manuscript drafting and revision; final approval. Anne Cotten: Conception and design of the study; manuscript drafting and revision; final approval.

References

- [1] Kiljunen T, Kaasalainen T, Suomalainen A, Kortensniemi M. Dental cone beam CT: A review. *Phys Med* 2015;31:844–60.
- [2] Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspects of dental CBCT: state of the art. *Dentomaxillofac Radiol* 2015;44:20140224.
- [3] Scarfe WC, Farman AG. What is cone-beam CT and how does it work? *Dent Clin North Am* 2008;52:707–30,
- [4] Zbijewski W, De Jean P, Prakash P, Ding Y, Stayman JW, et al. A dedicated cone-beam CT system for musculoskeletal extremities imaging: design, optimization, and initial performance characterization. *Med Phys* 2011;38:4700–13. .
- [5] Carrino JA, Al Muhit A, Zbijewski W, Thawait GK, Stayman JW, et al. Dedicated cone-beam CT system for extremity imaging. *Radiology* 2014;270:816–24.
- [6] Barg A, Bailey T, Richter M, de Cesar Netto C, Lintz F, et al. Weightbearing Computed Tomography of the Foot and Ankle: Emerging Technology Topical Review. *Foot Ankle Int* 2018;39:376–86.
- [7] Lintz F, de Cesar Netto C, Barg A, Burssens A, Richter M, Weight Bearing CT International Study Group. Weight-bearing cone beam CT scans in the foot and ankle. *EFORT Open Rev* 2018;3:278–86.
- [8] Watanabe H, Honda E, Tetsumura A, Kurabayashi T. A comparative study for spatial resolution and subjective image characteristics of a multi-slice CT and a cone-beam CT for dental use. *Eur J Radiol* 2011;77:397–402.
- [9] Tschauner S, Marterer R, Nagy E, Apfaltrer G, Riccabona M, et al. Surface radiation dose comparison of a dedicated extremity cone beam computed tomography (CBCT) device and a multidetector computed tomography (MDCT) machine in pediatric ankle and wrist phantoms. *PloS One* 2017;12:e0178747.
- [10] Demehri S, Muhit A, Zbijewski W, Stayman JW, Yorkston J, et al. Assessment of image quality in soft tissue and bone visualization tasks for a dedicated extremity cone-beam CT system. *Eur Radiol* 2015;25:1742–51.
- [11] Veldhoen S, Schöllchen M, Hanken H, Precht C, Henes FO, et al. Performance of cone-beam computed tomography and multidetector computed tomography in diagnostic imaging of the midface: A comparative study on Phantom and cadaver head scans. *Eur Radiol* 2017;27:790–800.
- [12] Dubreuil T, Mouly J, Ltaief-Boudrigou A, Martinon A, Tilhet-Coartet S, et al. Comparison of Cone-Beam Computed Tomography and Multislice Computed Tomography in the Assessment of Extremity Fractures. *J Comput Assist Tomogr* 2019;43:372–8.
- [13] Koivisto J, van Eijnatten M, Kiljunen T, Shi XQ, Wolff J. Effective Radiation Dose in the Wrist Resulting from a Radiographic Device, Two CBCT Devices and One MSCT Device: A Comparative Study. *Radiat Prot Dosimetry* 2018;179:58-68.
- [14] Koivisto J, Kiljunen T, Wolff J, Kortensniemi M. Assessment of effective radiation dose of an extremity CBCT, MSCT and conventional X ray for knee area using MOSFET dosimeters. *Radiat Prot Dosimetry* 2013;157:515–24.
- [15] Koivisto J, Kiljunen T, Kadesjö N, Shi XQ, Wolff J. Effective radiation dose of a MSCT, two CBCT and one conventional radiography device in the ankle region. *J Foot Ankle Res* 2015;8:8..

- [16] Neubauer J, Neubauer C, Gerstmair A, Krauss T, Reising K, et al. Comparison of the Radiation Dose from Cone Beam Computed Tomography and Multidetector Computed Tomography in Examinations of the Hand. *RöFo - Fortschritte Auf Dem Geb Röntgenstrahlen Bildgeb Verfahr* 2016;188:488–93.
- [17] Pugmire BS, Shailam R, Sagar P, Liu B, Li X, et al. Initial Clinical Experience With Extremity Cone-Beam CT of the Foot and Ankle in Pediatric Patients. *Am J Roentgenol* 2016;206:431–5.
- [18] Yel I, Booz C, Albrecht MH, Gruber-Rouh T, Polkowski C, et al. Optimization of image quality and radiation dose using different cone-beam CT exposure parameters. *Eur J Radiol* 2019;116:68–75.
- [19] Borel C, Larbi A, Delclaux S, Lapegue F, Chiavassa-Gandois H, Sans N, et al. Diagnostic value of cone beam computed tomography (CBCT) in occult scaphoid and wrist fractures. *Eur J Radiol* 2017;97:59–64.
- [20] Neubauer J, Benndorf M, Ehrhrit-Braun C, Reising K, Yilmaz T, et al. Comparison of the diagnostic accuracy of cone beam computed tomography and radiography for scaphoid fractures. *Sci Rep* 2018;8:3906.
- [21] Posadzy M, Desimpel J, Vanhoenacker F. Cone beam CT of the musculoskeletal system: clinical applications. *Insights Imaging* 2018;9:35–45.
- [22] IRSN - Institut de Radioprotection et de Sûreté Nucléaire. Niveaux de Référence Diagnostique en Radiologie n.d.
- [23] Habib Geryes B, Hornbeck A, Jarrige V, Pierrat N, Ducou Le Pointe H, Dreuil S. Patient dose evaluation in computed tomography: A French national study based on clinical indications. *Phys Med* 2019;61:18–27.
- [24] Andresz S, Morgan J, Croüail P, Vermeersch F. Conclusions and recommendations from the 17th Workshop of the European ALARA Network “ALARA in emergency exposure situations.” *J Radiol Prot* 2018;38:434-439
- [25] Richter M, Lintz F, de Cesar Netto C, Barg A, Burssens A. Results of more than 11,000 scans with weightbearing CT - Impact on costs, radiation exposure, and procedure time. *Foot Ankle Surg Off J Eur Soc Foot Ankle Surg* 2019.
- [26] Kalia V, Fishman EK, Carrino JA, Fayad LM. Epidemiology, imaging, and treatment of Lisfranc fracture-dislocations revisited. *Skeletal Radiol* 2012;41:129–36.

Table 1: Detail of dose analysis by subgroup of joints. DLP: Dose-length product (in mGy.cm).

	Foot & Ankle			Knee		
	CBCT	MDCT SR	MDCT UHR	CBCT	MDCT SR	MDCT UHR
n	63	28	62	20	35	2
Mean DLP (mGy.cm)	109,6	40,9	368,1	108,5	107,2	147,0
Std Dev.	9,9	8,0	95,8	8,6	42,8	1,4

	Hand & Wrist			Elbow		
	CBCT	MDCT SR	MDCT UHR	CBCT	MDCT SR	MDCT UHR
n	46	8	71	10	27	17
Mean DLP (mGy.cm)	85,5	36,0	204,7	111,3	184,3	221,6
Std Dev.	11,0	12,1	51,2	0,12	137,5	38,8

CBCT: Cone-Beam CT; MDCT: Multi-Detector CT; SR: Standard Resolution; UHR: Ultra-High Resolution.

LEGENDS TO FIGURES

Figure 1: Example of image quality obtained using Cone-Beam CT (CBCT). Knee trauma in a 33-year-old man. Conventional radiography showed a focal lateral tibial plateau fracture (A.), better evaluated on CBCT both in coronal plane using a bone window (B.) and through volume-rendering reconstruction of CBCT images (C).

Figure 2: Mean Dose-Length Product (DLP in mGy.cm) in each period. In period 1, only Multi-Detector CT (MDCT) was available for cross-sectional assessment of patients with trauma of the extremities. In period 2, both a MDCT and a Cone-Beam CT (CBCT) were available. Overall, the availability of CBCT enabled a 34.2 % decrease in the mean DLP (****: $p < 0.0001$).

Figure 3: Mean Dose-Length Product (DLP in mGy.cm) by type of acquisition protocol. Cone-Beam CT (CBCT); Multi-Detector CT (MDCT); Standard Resolution (SR); Ultra-High Resolution (UHR). Mean DLP in CBCT examinations was significantly lower than overall DLP in MDCT examinations (****: $p < 0.0001$). While DLP in CBCT was not significantly different from MDCT examinations performed in Standard Resolution (SR) (n.s.: non-significant), CBCT provided image quality of UHR type, with significantly lower irradiation (****: $p < 0.0001$).

Figure 4: Dose analysis by subgroup of joints. DLP: Dose-length product (in mGy.cm). Cone-Beam CT (CBCT); Multi-Detector CT (MDCT); Standard Resolution (SR); Ultra-High Resolution (UHR). While CBCT provided images of UHR quality, UHR MDCT delivered significantly more radiation, especially in foot, ankle, hand, wrist (****: $p < 0.0001$) and elbow (*: $p < 0.05$) examinations.

Figure 5: Length of stay in the Emergency Radiology Department (time between initial X-ray and final report, in minutes) for patients who underwent complementary cross-sectional imaging following extremity trauma. *: $p < 0.05$; ****: $p < 0.001$. In period 1, only Multi-Detector CT (MDCT) was available for cross-sectional assessment of patients with a trauma of the extremities. In period

2, both MDCT and Cone-Beam CT (CBCT) were available. The availability of CBCT enabled a 23.6% acceleration in turnover in period 2.



A.



B.



C.







