Imaging of midface fractures—a retrospective study

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ABSTRACT

AIM: To determine the number of patients that received plain facial view radiographs as well as computed tomography (CT) scans in diagnosing their midface fractures.

METHODS: Data was collected from our department of maxillofacial surgery trauma database. Patients with midface fractures sustained over an 18-month period were included (n=207) and further categorised into two groups; single-system facial trauma or multi-system trauma. Patient demographics, mechanism of injury, fracture location, modality of imaging and treatment were recorded.

RESULTS: Of those with single-system facial trauma (n=158), 9% received plain films only, 50.5% received CT imaging only, while 40.5% received both plain films and CT. Of the population that received plain films, 82.1% of patients required a further CT scan to aid in diagnosis and treatment planning. Of those patients who received both modalities of imaging, 70% were surgically managed to reduce and/or fixate their fractures. All 49 patients with multi-system trauma received a brain/head CT as part of their routine trauma work-up, and 46 of these patients had adequate midface views included in this scan (93.9%). However, 6.1% of patients needed an additional facial bones CT for diagnosis of facial fractures.

CONCLUSIONS: 40.5% of patients with single-system facial trauma received both plain radiographs as well as CT imaging. Additionally, 82.1% of all patients who had plain radiographs went on to have a further facial CT. Furthermore, 70% of these patients were surgically managed, inferring that this population may have benefitted from receiving a CT scan from the outset. This is not in line with the standard for pre-operative imaging of midface fractures in the literature, and a clinical pathway could be implemented across the Midland district health boards to guide the clinician in requesting appropriate pre-operative imaging of these fractures. This will aim to avoid delays in diagnosis, reduce radiation burden and create improved surgical planning and outcomes for our patients, while also enhancing healthcare resource allocation.

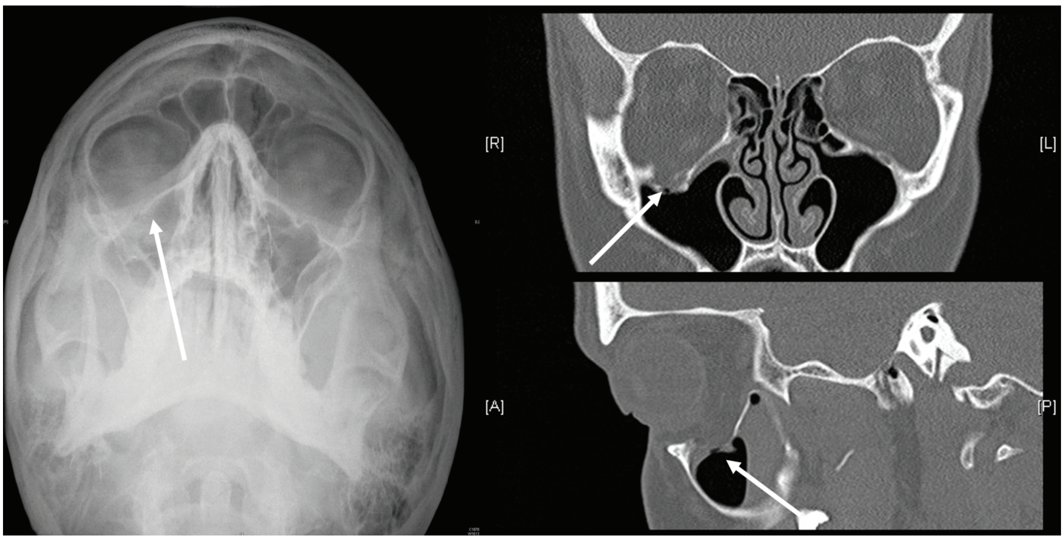
Midface fractures are routinely seen at the Waikato Hospital department of maxillofacial surgery, and currently the pre-operative imaging of these fractures is not standardised. These fractures include various combinations of zygomatic complex, arch, orbital, maxillary and nasoethmoidal fractures. This department provides tertiary level services to the Midland Health Region in the central North Island consisting of the Waikato, Lakes, Taranaki, Bay of Plenty and Tairawhiti District Health Boards. This catchment area covers 56,728km^2 (21% of New Zealand's land mass) and provides service to approximately 898,300 people (19% of New Zealand's population).[12] Due to this large catchment area, a portion of patients undergo pre-operative imaging at peripheral hospitals or primary healthcare providers prior to transfer to Waikato Hospital. Currently, there is no streamlined process that delineates which patients should have a pre-operative computed tomography (CT) from the outset, and which can be adequately diagnosed with plain radiographs when a fracture of the midface is suspected. A recurring problem observed is that this creates major delays in the diagnosis of fractures, multiple visits to the hospital for the patient and subsequent delays to surgery. Some patients receive as many as 12 plain facial films prior to CT imaging and as a consequence additional, and often avoidable, radiation. This will also have an impact on resource allocations in both radiology and surgical departments.

A New Zealand paper by Moore et al in 2015 has previously examined the characteristics, aetiology and treatment patterns of maxillofacial fractures at the Waikato Hospital over a 10-year period. The key findings from this study was that interpersonal violence was the most common cause of maxillofacial injury (54.5%) and associated with significant social cost and personal morbidity.[10] There are currently however, no New Zealand studies that examine the pre-operative imaging modalities of facial fractures and in particular, fractures of the midface.

The role of pre-operative imaging is to identify fractures, determine the extent of fracture displacement, and visualise stable bone for repair while also ruling out other injuries. Prior to computed tomography, two-dimensional plain films were considered adequate for pre-operative diagnostics of midfacial fractures. A limitation of plain imaging is that although it may reveal a fracture, it does not give an idea on the degree of fracture displacement, nor on the involvement of soft tissues (eg, extraocular muscle injury). Overall this offers limited information to the surgeon about the extent of the fracture, or the need for reduction. Furthermore, many fractures may be difficult to diagnose on plain films, in particular orbital floor and medial wall defects (Figure 1). Patients with the appropriate signs, symptoms and/or a high velocity mechanism of injury almost always require a CT for further detail on their fracture diagnosis and surgical planning. An exception of this is an isolated zygomatic arch fracture, which can be adequately visualised on a plain submentovertex (SMV radiograph).[9,15,17]

CT has increased sensitivity for facial fracture detection when compared to plain radiography. It also has a high accuracy for both bony and soft tissue injury and is currently considered the gold standard of care for midfacial trauma.[2] Along with confirmation of a clinical diagnosis, CT allows for accurate pre-surgical planning through the use of digital 3D reconstruction, the fabrication of a custom made biomodel, as well as incorporation into intra-operative navigational software. All of these tools contribute towards accurate diagnosis, treatment planning and appropriate patient selection while also reducing operative time and potential complications. Undoubtedly this allows for a more favourable surgical outcome for the patient.[19] Furthermore, three-dimensional imaging aids patient understanding and education about the nature of their injury and the treatment required. A 3D biomodel can be used pre-operatively to illustrate to the patient the extent of their fracture and the benefit of reduction or reconstruction, allowing them to make a more informed decision during the consent process.

Figure 1: Right orbital floor fracture visualised on the coronal and sagittal slices of a facial bones CT scan which was failed to be diagnosed on an occipitomental plain film.



When comparing the effective radiation dosage of plain film and CT, patients receive an effective dose of 0.92 mSv per non-contrast facial bones CT (vertex to maxillary alveolar process). This is approximately half the effective dosage received in a conventional CT brain (1.84 msV). In comparison, facial plain films can vary in effective dosage from 0.01–0.22 mSv depending on the type of film taken.[3] When a series of 3–4 plain films are utilised, this radiation dose can cumulate to a total dose to be comparable to that of a facial bones CT. Furthermore, if a CT scan is taken in addition to plain films the dose can be significant.

The aim of this study is to determine the number of patients with midface fractures seen at the Waikato Hospital's department of maxillofacial surgery that received plain facial radiographs as well as computed tomography (CT) in diagnosing their fractures. The results will be compared to current recommendations, and whether change can be implemented on how we image our patients.

Methods

Data was extracted from the department of maxillofacial surgery's trauma database. Patients with midface fractures (classified as fractures between the supraorbital rim and alveolus of the maxilla) between 1 January 2015 and 17 June 2017 were identified. This included patients that were seen at the Waikato Hospital emergency department, as well as those referred from other hospitals under the regional district health boards, as well as direct referrals from general practitioners. Midface fractures were classified as fractures of the orbit (rim, wall(s), floor), zygomatic arch, zygomaticomaxillary complex (ZMC), nasoorbitoethmoidal (NOE) complex, and Le Fort 1, 2, 3 type pattern fractures. Patient demographics, mechanism of injury, fracture location, modality of imaging and treatment were recorded. Patients with invalid or incomplete details recorded (such as absent National Health Index [NHI] numbers) were excluded, as well as those whose imaging could not be accessed for review.

The resulting population was divided into two categories based on the severity of trauma sustained. The first group of patients were classified under single-system facial trauma. This group sustained isolated facial injuries without a suspected intracranial injury, thus they did not require a CT head/brain as part of their initial screening. The second group were classified under multi-system trauma as these patients sustained midface fractures as part of poly-trauma and required a full trauma CT series (eg, CT head, neck, chest, abdomen, pelvis). Furthermore, we analysed whether these CT head scans included slices of the facial bones to determine if there were any underlying facial injuries. The results were tabulated and analysed.

Results

Four patients were excluded due to incomplete information. The final study population included 207 patients, comprising of 76.8% (n=159) males and 23.2% (n=48) females. The greatest proportion of patients, 24.2% (n=50), was aged between 20–29, followed by 20.78% (n=43) aged between 30–39, 11.6% (n=24) aged between 10–19 and 11.6% (n=24) aged between 50–59 (Figure 2).

Figure 2: Patient distribution by age.

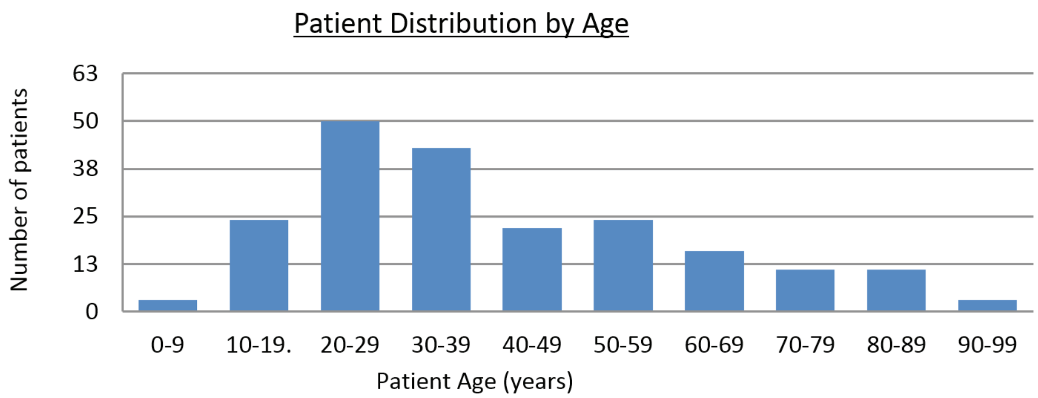
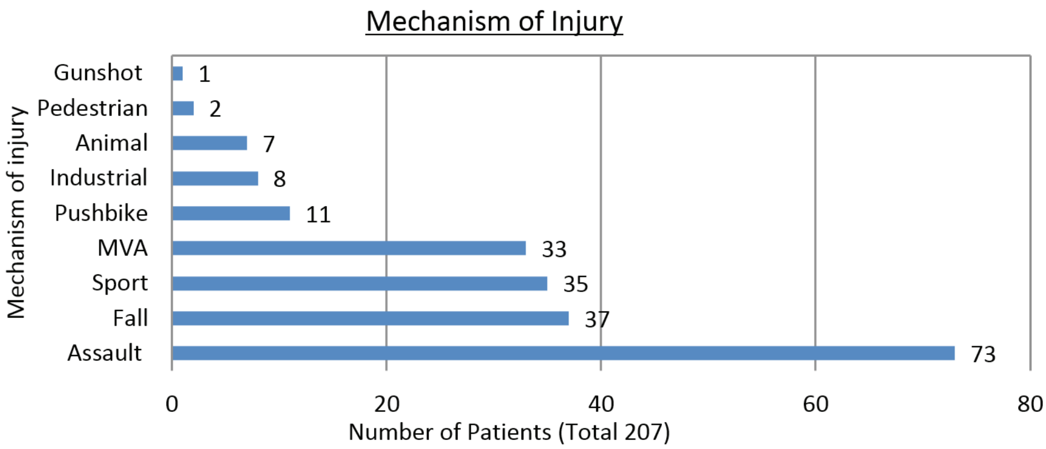


Figure 3: Patient distribution by mechanism of injury.



The predominant mechanism of injury was alleged assault, accounting for 35.7% (n=73) of the total 207 cases. This was followed by falls 17.9% (n=37), sporting related injuries 16.9% (n=35) and motorvehicle accidents 15.9% (n=33). The remainder were pushbike 5.3% (n=11), industrial accidents 3.9%(n=8), animal related injuries 3.4% (n=7), pedestrian (n=2) 1.0% and gunshot accidents 0.5% (n=1) (Figure 3).

The most prevalent fracture locations were isolated orbital and zygomaticomaxillary complex injuries with 46.9% (n=97) and 44.9% (n=93) respectively. Le Fort 1, 2 and 3 fracture patterns were identified in 8.7% (n=18) cases, followed by isolated zygomatic arch fractures 7.73% (n=16). Nasoorbitoethmoidal (NOE) and isolated nasal bone fractures were identified in 3.38% (n=7) and 2.4% (n=5) cases respectively (Figure 4).

The single-system trauma group formed 158 of the 207 patients. As these patients presented with isolated facial injuries, the screening clinician had the option of sending the patient for plain films or a CT scan after clinical assessment. Forty-nine patients were identified as being involved in multi-system trauma. This included all patients who received a full trauma CT scan including a brain CT.

Of the single-system facial trauma group, 8.9% (n=14) received plain films only, 50.6% (n=80) received a CT only, while 40.5% (n=64) had both plain films followed by a CT scan. Of interest, of 64 patients who had both modalities of imaging, 70.3% (n=45) were surgically managed. The remaining 29.7% (n=19) cases were treated conservatively after a clinical assessment and informed discussion (Table 1).

Figure 4: Fracture type by location.

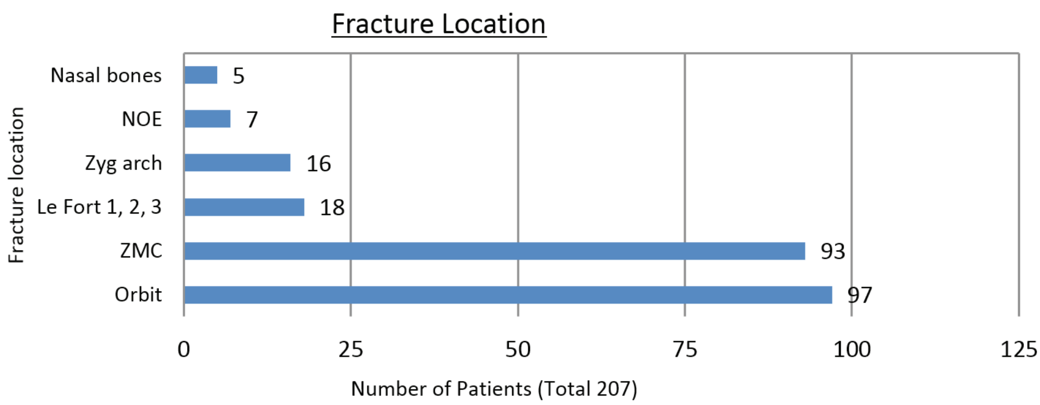


Table 1: Distribution of patients by imaging modality and treatment received involved in single-system facial trauma only.

	Plain films	CT	Plain films + CT	Total
Non-surgical	6	35	19	61
Surgical	8	44	45	98
Total	14	80	64	158

Of the 14 patients who received plain films only, eight sustained an isolated zygomatic arch fracture, three sustained isolated nasal bone fractures, two sustained an orbital floor fracture and one patient sustained a ZMC fracture. The two orbital fractures were clinically diagnosed due to the presence of clinical signs (diplopia, restricted eye movement, infra-orbital paraesthesia) but were not confirmed by CT imaging due to the patient or surgeon's decision and/or patient morbidity. Of the patients that received plain film only, eight were treated surgically (seven zygomatic arches, one zygomaticomaxillary complex). Six patients were treated non-surgically (three nasal bone fractures, two orbital floor fractures and one zygomatic arch fracture).

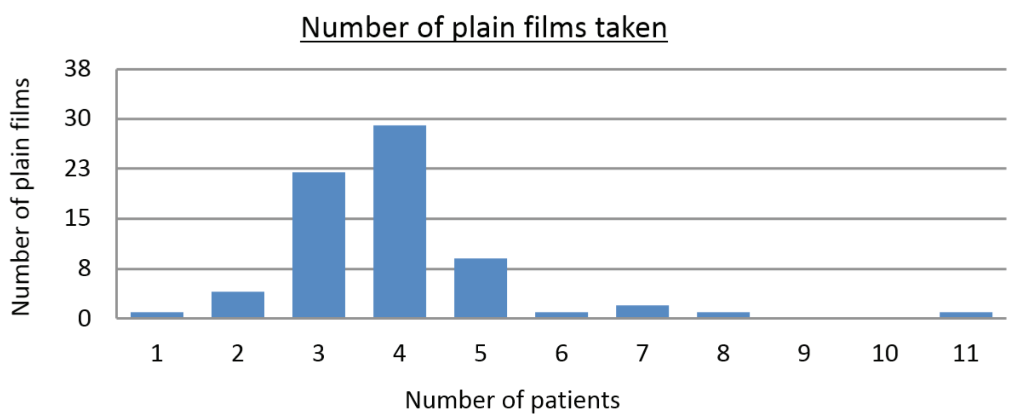
Of 49 patients involved in multi-system trauma, 100% (n=49) of patients had a CT brain. Of these 93.9% (n=46) patients had facial bone slices included in their original scan. Only 6.1% (n=3) of patients needed an additional CT scan to image the facial bones to diagnose their midface fractures.

A total of 78 (49.4%) of 158 patients with single-system facial trauma had plain radiographic films taken (eg, occipitomental, submentovertex views). Of these 78 patients, 82.1% (n=64) had to have a further CT scan to aid in diagnosis and/or treatment planning. The range of plain films taken was between two and 11 films per patient, while the mean number of films was 3.8 (Figure 5).

Discussion

In this study, records were retrospectively analysed to determine the modality of pre-operative imaging received by patients presenting through the department of maxillofacial surgery with midface fractures between 1 January 2015 and 17 June 2017. Many similarities in the population sample were observed when compared with the Moore et al study from 2015, which previously analysed all maxillofacial fractures seen through the unit over a 10-year period (between 2004–2013). The population in this study comprised of 76.8% male and 23.2% female patients. This is similar to the 2015 study, which observed a male to female ratio of 4:1 in all maxillofacial fractures, with 81.3% males and 18.7% females making up the study population. The most prevalent age group in this study was 20–29 years, accounting for 24.2% of all patients. This is

Figure 5: Number of plain films taken per patient with single-system facial trauma.



slightly lower than the 2015 study, which saw 38.4% patients identified in this age bracket. One possible explanation is that our population is not only living longer, but we are also suffering minor-moderate injuries (such as falls) resulting in fractures, the majority of which do not have indications for surgery. The predominant mechanism of injury in both studies was alleged assault or interpersonal violence (IPV), however the proportion was notably lower (35.7%) in this study when compared with Moore et al (54.4%). It is important to note that our current study included fractures of the midface only, and such differences could be attributable to other facial fracture sites being identified in Moore et al (eg, mandibular, frontal bone and alveolar fractures).[10]

When examining the literature, a significant number of international studies have found CT imaging demonstrating both higher specificity and sensitivity for detection of maxillofacial fractures. A paper by Ansari et al (2015) found that out of 173 maxillofacial fracture sites, 94 were detected on conventional radiographs while 166 fracture sites were detected on CT (96%).[1] Similar findings are reported by Sun and LeMay (2002), who found that computed tomography was superior to conventional radiography and MRI in detecting facial fractures, defining their direction, extent and displacement.[18] A further study by Dos Santos et al (2004) found that CT imaging had both higher specificity and sensitivity for maxillofacial fractures than plain films, and the clinical and surgical findings of multiplanar and 3D CT were considered the gold standard in diagnosing fractures and their anatomical locations.[4] In our study 49.4% of patients with single-system facial trauma had plain films taken, with 82.1% of these patients also obtaining a CT scan after assessment by the Maxillofacial Surgery team. This suggests plain imaging was inadequate for diagnosis and/or surgical planning in the vast majority of midface fracture management. Thus, there clearly is a need for a clinical pathway of best care to direct imaging studies based on history and clinical findings and reduce fragmentation in the acute services. In 2015, The University of Wisconsin established an inclusion criterion for the imaging of facial trauma to help providers evaluate and identify which patients required a CT scan which were at a low risk of fracture and could avoid imaging. The decision instrument included five physical examination criteria; bony step-off or instability, periorbital swelling or contusion, Glasgow Coma Scale (GCS) <14, malocclusion and tooth absence. Any one finding placed the patient at high risk of facial fracture. This decision instrument was found to be 97.4% sensitive for the presence of facial fractures, with a missed injury rate of 2.6%.[17]

However, an external validation of this decision instrument was later performed by Harrington et al 2018, to evaluate whether the criteria could be generalised to external institutions. This study was unable to validate the predictive criteria, with only 81% sensitivity for facial fractures when applying the Wisconsin tool at an external Level 1 tertiary trauma center.[6] A model founded on the principles of the Wisconsin criteria, and adapted with the inclusion of the energy/velocity of trauma sustained and additional clinical signs and symptoms of midface fractures could be developed and implemented at the hospital and the results audited. Clinical signs of these fractures include palpable step deformity of the bony orbital rim, flattening of the malar prominence, paraesthesia in the V2 distribution, diplopia, periorbital oedema and haematoma, malocclusion, epistaxis, nausea and vomiting with ocular movement, and in particular orbital entrapment.[14] In such cases diagnosis with a CT study should not be delayed as complications can develop, including retrobulbar haematoma, enophthalmos, persistent diplopia, poor cosmesis and functional abnormalities. Patients who present following low-velocity trauma with an absence of these signs can be radiographically assessed if indicated using a single OM plain film view as a first-line screening tool. A study by Pogrel, Podlesh and Goldman (2000) found that a single 30-degree OM radiograph, augmented with a CT when indicated, can accurately identify all midfacial fractures requiring treatment.[13] This suggests that the current practice of obtaining a series of plain radiographs is unnecessary. Over the period examined, the mean number of plain films taken at our district health board was 3.8, most of which were of little or no diagnostic value, given 80% were followed up with a CT scan. This is expected, as in a conventional x-ray, the two-dimensional nature of the image means complex bone structures of the facial skeleton overlap, decreasing sensitivity.[10] Most isolated nasal bones fractures often do not require imaging and can be diagnosed clinically, unless they are suspected to be part of more extensive facial injuries. In addition, zygomatic arch fractures can be sufficiently diagnosed with a single submentovertex view.

Patients presenting with head injuries can often present with concomitant facial fractures. A study by Huang et al (2017) evaluated the value of simultaneous facial CT scans in assessing facial fractures in patients with traumatic brain injury. Of their cohort of 1,649 patients, 200 (12.1%) were found to have at least one facial fracture on their CT scan when simultaneous head and facial CT scan were performed. Similarly, patients presenting with facial fractures may have associated head injuries. A case control study conducted at the Besat Hospital, Hamedan, Iran, found that the rate of head injuries associated with facial bone fractures was 23.3% in a cohort of 2,692 of patients admitted with maxillofacial trauma.[20]

As most patients undergo a brain CT when presenting following multi-system trauma, often the decision to add a facial bone CT to the scan is unclear. A retrospective five-year study by Holmgren et al (2004) identified that orbital fractures were commonly missed in this group of patients and frequently required a secondary scan. They also found that the use of facial CT in more severely injured patients tended to be delayed and was related to increased hospital and intensive unit days. In our study of the patients involved in multi-system trauma, 93.9% (46) of 49 patients had facial bones included at the time of their CT head. This is very high when compared with the findings from the level I trauma center reviewed by Holmgren et al, who found that only 16% of facial fracture patients who received an initial trauma head CT did not require a further facial CT scan.[7]

This is a retrospective study and thus there are limitations, including the inaccuracy of record-keeping in our facial trauma database. Furthermore, despite all imaging being reviewed by specialists, oral and maxillofacial surgeons and radiologists, there may be fractures missed. Thus, no specific information on plain radiograph fracture identification, sensitivity or specificity was gathered.

Conclusion

In this study, 40.5% of patients who sustained single-system facial trauma received both plain radiographs as well as a CT scan. Additionally, 82% of patients who had plain radiographs went on to have a further facial CT scan to diagnose and/or treat their midface fractures, thus receiving additional (and unnecessary) radiation. Furthermore, 70% of these patients were surgically managed, inferring that this population may have benefitted from receiving a CT scan from the outset. Given the current literature, the practice of taking multiple plain films for suspected midface fractures in our population group is not in line with the international standards, which advocate that pre-operative CT scanning should be the modality of choice for midface injuries when clinical signs are present.

Currently there is not a pragmatic pathway across the Midland district health boards that outlines to the assessing clinician the appropriate imaging for single-system facial trauma, or suspected facial fractures as part of multi-trauma. Our recommendation is that a clinical pathway is developed with multispeciality involvement of the maxillofacial, emergency medicine and radiology departments, and implemented across hospitals in the Midland region. This pathway should aim to identify which patients do not need imaging and of those that do, which only require plain films and which should directly proceed to CT. Furthermore, these recommendations could be extended to all district health boards across New Zealand.

Our proposed pathway is that for single-system facial trauma patients, all patients with clinical signs (step deformity, periorbital oedema, infra-orbital paraesthesia, restricted eye movement, diplopia) should have a CT scan and bypass plain film imaging. This scan could be conducted as an inpatient (if admitted to hospital) or outpatient and thus should not prolong wait times in the emergency department, nor stretch after-hours radiology services. Clearly if there is an emergent situation (eg, retrobulbar haemorrhage) then an urgent CT scan should be considered along with appropriate emergency management. As indicated by evidence in the literature, those patients who do not have clinical signs of midfacial fractures (but a significant mechanism of injury/history) should have a single OM view. If following radiographic review of the OM plain film there is suspicion of a fracture, these patients should go on to have an additional CT scan. A further prospective study could be conducted to evaluate the results of this protocol. For patients involved in multi-system trauma, we recommend that all patients who have a brain CT scan should also have a facial CT scan as our study found that 6.1% of this group had to be re-scanned.

This pathway would improve resource allocation across the Midland hospital services, enhance initial fracture detection, as well as reduce the radiation exposure and surgical delays in the management of patients with midface fractures as part of both single-system and multi-system trauma.

Competing interests:
Nil.
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