Introduction of a simple guideline to improve neurological assessment in paediatric patients presenting with upper limb fractures

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▸ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/emermed-2014-204414).

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Received 15 October 2014
Revised 30 August 2015
Accepted 25 January 2016
Published Online First 15 February 2016

ABSTRACT

Background Neurological examination in children presenting with upper limb fractures is often poorly performed in the Emergency Department (ED). We aimed to assess the improvement in documented neurological examination for children presenting with upper limb fractures following introduction of a simple guideline.
Methods We developed and introduced a simple guideline for upper limb neurological assessment in children ('rock, paper, scissors, OK'). We compared documentation of neurological examination and nerve injury detection at our hospital before and after introduction of this guideline, as well as for children admitted from external hospitals (where the guideline had not been introduced).
Results In the period following guideline introduction, 97 children with upper limb fractures were admitted (46% presenting directly to our ED and 54% admitted from external hospitals). This cohort was similar in number and distribution to the cohort reviewed prior to the guideline. Documentation of neurological examination in our ED increased from 92% to 98% after guideline introduction. Documented information on nerves examined also increased from 2% to 68% ($p<0.01$). Prior to the guideline, there were six nerve injuries, all of which were missed in our ED. After guideline introduction, there were four nerve injuries, all of which were detected in our ED. Documentation and nerve injury detection at external hospitals over the same time period showed no improvement.
Conclusions A simple guideline to assist neurological examination in children with upper limb fractures can significantly improve the quality of documented neurological assessment and nerve injury detection.

Key messages

What is already known on this subject?
Neurological examination in children with upper limb injuries can be challenging. Nerve injuries associated with upper limb fractures in children are frequently undetected at initial assessment.

What might this study add?
A simple guideline for neurological assessment of upper limb injuries can significantly improve detection of associated nerve injuries.

BACKGROUND

Upper limb fractures account for over 80% of all paediatric fractures presenting to Emergency Departments (EDs).[1] Of these, distal radial fractures occur most commonly followed by supracondylar humeral fractures.[2] Most upper limb fractures result from falls or injuries during sporting activities, although there is an increasing incidence of trampoline-related trauma.[3]

Nerve injury occurs in approximately 1% of children's forearm fractures and is usually a neurapraxia.[4] The incidence increases with more comminuted fractures and open injuries to approximately 10%.[5] Neurological injury associated with humeral supracondylar fractures has varied from 8% to 20% in the literature.[6] A recent meta-analysis reported neurological injury in 11.3% of displaced supracondylar fractures.[7] Median, ulnar and radial nerve injuries may all be associated with these fractures. However, the anterior interosseous branch of the median nerve is the most commonly involved.

Neurological injury may also occur during fracture reduction and fixation. It may result from traction to the nerve during closed manipulation or from direct trauma during percutaneous or internal fixation. Nerve injury associated with reduction and K-wire fixation of supracondylar fractures has an incidence of approximately 3% and may be reduced by using laterally placed divergent wires or visualising the ulna nerve if a medial wire is used.[7] Accurate neurological assessment and clear documentation preoperatively and postoperatively is therefore important to determine whether a postoperative nerve injury may have been iatrogenic.

In the ED, neurological examination may be compromised by a child's pain, distress or other distracting injuries. In younger children, communication difficulties may further confound this assessment. Mayne *et al*[8] reviewed 137 humeral supracondylar fractures and found that documentation of a complete neurological examination (motor and sensory function recorded) occurred in only 9% of cases. In our hospital, we reviewed initial documentation of neurological examination for children with upper limb fractures. Although neurological examination was documented in 92% of cases, only 2% detailed which nerves had been assessed.[9]

The use of a guideline or pro forma to assist neurological examination in children with upper limb injuries has been suggested previously and introduced to some units.[8] However, the efficacy of

To cite: Marsh AG, Robertson JS, Godman A, *et al*. *Emerg Med J* 2016;**33**:273–277.

such guidelines has not been reported, nor is it clear whether they act as a teaching aid. We aimed to determine whether introduction of a simple neurological examination guideline ('rock, paper, scissors, OK') could improve documented neurological examination in children presenting with upper limb fractures to our unit and in turn improve detection of associated nerve injuries. We also aimed to assess the impact of this guideline on the knowledge of ED staff regarding neurological examination.

METHODS

In August 2011, we developed a guideline for upper limb neurological assessment in children (see online supplementary appendix 1). This guideline highlighted a simple sensory and motor examination for the most common nerves injured in upper limb paediatric fractures (median, ulnar, radial and anterior interosseous). The motor assessment involved simple actions for these nerves based on the children's game Rochambeau ('rock, paper, scissors') and included the 'OK' sign to test anterior interosseous nerve (AIN) function.[10 11] The guideline was reviewed by the clinical lead of the ED in our hospital and, with their approval, disseminated in written form and displayed in the department. In addition, the guideline was presented to emergency doctors starting their rotation at induction teaching sessions. To ensure all ED junior doctors (FY doctors, core trainees, specialty registrars) received information on the guideline, attendance was taken at these sessions and confirmed against staff records for the ED department at the time of the study.

Nine months following introduction of the guideline, we analysed the clinical notes of all children with upper limb fractures admitted to the orthopaedic department at the Royal Hospital for Sick Children, Glasgow over a 3-month period (May 2012–July 2012). These patients were either admitted directly from our own ED or transferred following review at EDs in other regional hospitals. All cases were identified on a daily basis from the orthopaedic ward admission records. To ensure no cases were missed, we cross-checked our data with the orthopaedic ward discharge letters as well as attendance and destination records for all EDs admitting children to our unit. This included the ED at our own hospital and EDs at external hospitals.

The ED assessment chart for each child was analysed by a single reviewer (JB) and information recorded using a data abstraction sheet. The reviewer was blinded to the study hypothesis at the time of data collection. Information collected included patient demographics, time of presentation to the ED, injury sustained, mechanism of injury, documented clinical examination, initial management in the ED (including analgesia administered) and subsequent definitive treatment. Information about clinical examination included time of assessment, documented neurological examination and documented suspicion of any nerve injury. Details of neurological examination were transcribed on the data abstraction sheet verbatim from the ED chart. Documentation was then categorised into the following groups: neurovascularly intact (NVI) documented with no mention of nerves examined, individual nerve examination documented, motor examination only documented, sensory examination only documented, no documentation. Documentation of neurological assessment performed in the ED was compared with the examination findings of the admitting orthopaedic team.

The results from the current study period (following guideline introduction) were then compared with those from our previously published study, where we reported the quality of documented neurological examination for children presenting with upper limb fractures prior to guideline development.[9] This study involved a similar review of the clinical notes of all children with upper limb fractures admitted to our orthopaedic unit over a similar 3-month period (May 2011–July 2011). These data were collected using the same methods as in the study period following guideline introduction. A single reviewer (JSR) was responsible for analysing all of the ED assessment charts with information recorded using the same data abstraction sheet. Information collected again included details of clinical assessment in the ED and any detection of associated nerve injuries. This allowed us to determine any change in clinical practice. All children were also either admitted directly from our own ED or following assessment in the ED of other local units. We were therefore able to compare neurological assessment in our own ED with external hospitals where the guideline had not been introduced.

In parallel to data collection for the previously reported study, we invited all ED medical staff at our hospital to complete a questionnaire on upper limb neurological examination. This aimed to assess baseline knowledge of neurological assessment and included questions about frequency of neurological examination for children presenting with upper limb fractures and which nerves should be commonly examined. We also asked for a brief description of the neurological examination they would perform to assess individual upper limb nerves.

Following introduction of our neurological assessment guideline, ED medical staff at our hospital were invited to complete the same questionnaire on upper limb neurological examination to determine any change in knowledge.

Data from both time periods were collated, analysed and compared. Fisher's exact test was used for comparison of neurological documentation before and after guideline introduction, as datasets could not be assumed to follow a normal distribution and the sample size in comparative groups was relatively small. Similarly, Wilcoxon rank sum test was used to compare times from presentation to clinical assessment in EDs. All statistical tests were performed using SPSS V.18.0.

Ethics committee approval was not required as this was a quality improvement initiative.

RESULTS

The results for the initial study period (May 2011–July 2011) have previously been reported, but for ease of comparison have been summarised under 'cohort 1' in the results section.[9] During this period, there were 121 paediatric admissions from EDs with upper limb fractures requiring either closed manipulation or operative fixation. Of these, 60 (50%) were admitted from our own ED with the remainder referred from external hospitals. The period that is the focus of the current study, following introduction of the guideline, (May 2012–July 2012) has been summarised in the results section as 'cohort 2'. During this period, there were 97 admissions, with 45 (46%) admitted directly from our own ED. The demographics of the two cohorts are shown in table 1. Age ranges were similar. However, in the second cohort, a greater proportion of boys were admitted.

All patients admitted with upper limb fractures during the study periods (cohort 1 and cohort 2) sustained isolated upper limb injuries only. Overall, injuries did not vary significantly between the cohorts. The most common injuries were combined radius and ulna fractures (40% in first cohort, 48% in second cohort), isolated radial fractures (26%, 21%) and supracondylar distal humeral fractures (18%, 21%). The mechanisms of injury were also similar across both study groups with the most common injury being a simple fall (42%, 45%). Fractures

Table 1 Demographics of paediatric patients admitted in initial and follow-up study periods

	Cohort 1 (n=121)*	Cohort 2 (n=97)†
Sex		
Male (%)	61 (50)	65 (67)
Female (%)	60 (50)	32 (33)
Age		
0–2 years (%)	8 (7)	7 (7)
3–5 years (%)	36 (30)	37 (38)
6–8 years (%)	41 (33)	30 (31)
9–12 years (%)	36 (30)	23 (24)
Injury sustained		
Radius and ulna fracture (%)	48 (40)	47 (48)
Radius fracture (%)	32 (26)	20 (21)
Supracondylar distal humerus fracture (%)	22 (18)	20 (21)
Lateral condyle fracture (%)	8 (7)	6 (6)
Medial condyle fracture (%)	4 (3)	1 (1)
Dislocated elbow (%)	4 (3)	2 (2)
Ulna fracture (%)	2 (2)	1 (1)
Olecranon fracture (%)	1 (1)	0 (0)
Mechanism of injury		
Fall (%)	51 (42)	44 (45)
Trampoline (%)	19 (16)	14 (15)
Climbing frame (%)	19 (16)	13 (14)
Bicycle (%)	12 (10)	10 (10)
Sport (%)	9 (7)	8 (8)
Swings (%)	9 (7)	5 (5)
Slide	2 (2)	3 (3)
Median time to assessment in ED		
Minutes (range)	10 (0–30)	10 (0–40)
Median dose of diamorphine (mg)		
0–2 years (range)	1.2 (0.9–1.3)	1.2 (1–1.3)
3–5 years (range)	1.6 (1.4–1.8)	1.7 (1.4–1.8)
6–8 years (range)	2.8 (2.6–3.0)	2.8 (2.6–3.0)
9–12 years (range)	3.8 (3.4–4.0)	3.8 (3.4–4.0)

*Cohort 1 represents data from initial study period (May 2011–July 2011) and has been reproduced from Robertson *et al*.[9]
†Cohort 2 represents data from the follow-up study period (May 2012–July 2012).

Table 2 Comparison of documented neurological assessment for patients admitted in initial and follow-up study periods

	Hospital	Cohort 1*	Cohort 2†	p Value‡
Number of children Assessed in ED with an upper limb injury (%)	RHSC External hospitals	60 (50) 61 (50)	45 (46) 52 (54)	
Number of children with a documented neurological examination (%)	RHSC (%) External hospitals (%)	55 (92) 51 (84)	44 (98) 45 (87)	0.04 0.79
Number of children with a neurological examination describing which nerves were assessed (%)	RHSC (%) External hospitals	1 (2) 4 (8)	30 (68) 5 (11)	<0.01 0.73

*Cohort 1 represents data from initial study period (May 2011–July 2011) and has been reproduced from Robertson *et al*.[9]
†Cohort 2 represents data from the follow-up study period (May 2012–July 2012).
‡Fisher's exact test.
ED, Emergency Department; RHSC, Royal Hospital for Sick Children.

sustained from recreational play included trampoline injuries (16%, 15%), falls from climbing apparatus (16%, 14%), falls from swings (7%, 5%) and falls from slides (2%, 3%). Injuries from sporting activities accounted for less than 10% of injuries in both cohorts (7%, 8%).

All children in the study were clinically assessed within 1 h of presentation to the ED. This included patients admitted directly from our own ED and those reviewed at external hospitals. The median time from presentation to the ED and clinical assessment was similar between children in cohort 1 (median time to assessment 10 min, range 0–30 min) and cohort 2 (median time to assessment 10 min, range 0–40 min) (p=0.86, Wilcoxon rank sum test).

Analgesic requirements did not vary between cohorts. All patients were given simple analgesia (paracetamol and ibuprofen) as well as intranasal diamorphine following clinical assessment at triage. The median doses of intranasal diamorphine administered did not vary between children in cohort 1 and cohort 2.

Documentation

In cohort 1, documentation of neurological status was similar between those admitted from external hospitals and those attending our own ED (table 2 and figure 1). At our own hospital, neurological status was documented in 92% of patients, with the majority (88%) evaluated as 'neurovascularly intact'. However, only 2% had any documented evidence of which nerves had been assessed. Similarly, at external hospitals, neurological status had been recorded in 84% of patients with the phrase 'neurovascularly intact' used in 70% of cases. Details of individual nerves assessed were only present in 8% of cases. In both groups, no mention was made of AIN examination in any child.

For cohort 2, following introduction of the guideline, there was an improvement in documentation of neurological examination for patients admitted from our ED. Overall documentation of neurological status increased to 98% (p=0.04, Fisher's exact test). Documentation of which nerves had been examined also increased to 68% (p<0.01). In two cases, there was still no documented neurological examination. In contrast, patients from cohort 2 admitted from external hospitals had no significant change in documented neurological assessment (87%, p=0.79). In addition, details of nerves assessed during examination only occurred in 11% of patients (p=0.73).

Nerve injury detection

In cohort 1, there were 10 patients who sustained nerve injuries (9%). The most common type of injury producing a neurological deficit was a supracondylar fracture (4, 40%). Six of these were admitted directly from our ED. In all cases, the nerve injury was not diagnosed from initial examination in the ED and the majority had a neurological examination documented as 'neurovascularly intact'. In cohort 2, there were eight nerve injuries. Of the four who presented directly to our ED, all were detected and documented at initial assessment. None of the injuries assessed in external hospitals were diagnosed (table 3).

Clinician knowledge

Prior to the introduction of the guideline, the questionnaire responses revealed considerable difference in knowledge and practice between junior members and consultants. While ED consultants reported always examining peripheral nerves in children with upper limb fractures, only 75% of foundation/core

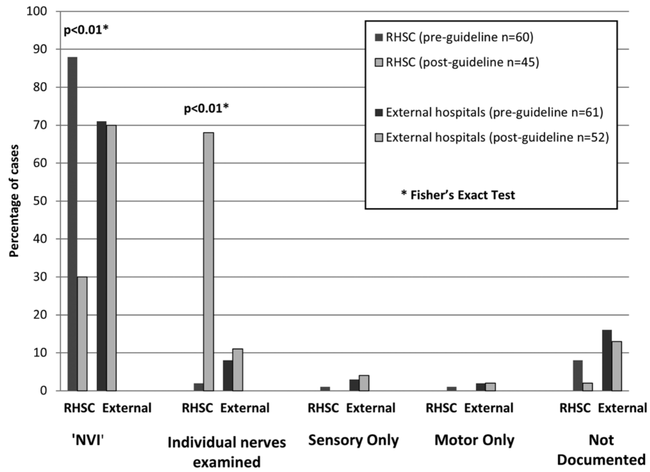

Figure 1 Documentation of neurological examination by ED staff before and after introduction of the guideline. NVI, neurovascularly intact; RHSC, Royal Hospital for Sick Children.

trainee doctors and 78% of registrars, respectively, stated they would routinely carry out a neurological examination. In addition, consultants were the only group who identified the need to examine the AIN. Despite this, 31% of foundation doctors/core trainees and 12% of registrars described an examination technique which would test AIN function as part of their median nerve assessment. Following guideline introduction, all emergency medical staff stated they would routinely perform a neurological examination in patients with upper limb injuries. Surprisingly, even after introduction of the guideline, the percentage of clinicians in each grade who could describe an adequate assessment of each nerve did not improve (figure 2).

DISCUSSION

Our results show the introduction of our guideline significantly improved the documentation of neurological examination for paediatric upper limb injuries. There were a greater proportion of patients with a documented neurological examination and increased information on which nerves had been assessed. In addition, we showed a significant increase in the detection of nerve injuries from initial examination performed in the ED at our hospital (cohort 1 vs cohort 2). Referrals to our unit from external hospitals where the guideline was not available showed no improvement during the same time period (cohorts 1 and 2).

We have previously reported that although neurological examination was documented for over 90% of patients presenting to the ED with upper limb injuries, in the majority of cases, it was not clear how complete an examination had been performed, or which nerves had been assessed.[9] In addition, all nerve injuries remained undetected at the time of initial assessment in the ED. Similar findings have been reported for documentation of neurological assessment for paediatric supracondylar fractures, with these authors recommending use of a pro forma to facilitate nerve injury detection.[8]

Any such pro forma or guideline assisting paediatric upper limb nerve assessment needs to describe simple examination techniques that are easily followed by children of different ages. Motor and sensory assessment for individual nerves should also be repeatable and comprehensible for clinicians of different experience. Despite the requirement to provide simple examination methods, the guideline must still allow detection of any potential neurological injury.

We developed and introduced our own guideline (rock, paper, scissors, OK) for neurological assessment in children with upper limb injuries. This was a simple and memorable aid to evaluating sensory and motor function of the four most common nerves (median, ulnar, radial and AIN) at risk in paediatric upper limb injuries.

All paediatric patients examined using our guideline, were able to cooperate with the neurological assessment and no problems with age-related understanding of this were reported. Despite this, we acknowledge that neurological examination in very young children can be particularly challenging. The age range of patients assessed using our guideline (cohort 2) was 20 months to 12 years. Therefore, we do not have evidence of the suitability of this guideline for those younger than 20 months. However, in younger children, modification of our guideline, taking into account comprehension and developmental stage, may be helpful to optimise neurological assessment. For example, rather than using 'rock, paper, scissors', the hand actions for the nursery rhyme 'twinkle, twinkle little star' may be more familiar to younger children and still allow motor assessment of median, ulnar and radial nerves. In addition, simple observation of spontaneous hand movements may provide important information about nerve function even before any formal assessment is performed.

The improvement in documented neurological examination, as well as nerve injuries detected, suggests that our guideline has improved clinical assessment in children with upper limb fractures. The results from our questionnaires would also suggest that the guideline has improved awareness of the importance of neurological assessment in upper limb injuries, especially among junior emergency medical staff (foundation doctors/core trainees). However, despite introducing the guideline alongside a teaching session for emergency doctors, we have not

Table 3 Details of nerve injuries in cohort 2

Age (years)	Neurological deficit	Injury	Initial documentation	Hospital attended	Nerve injury documented
5	Radial palsy	Ulna and radius*	NVI	External	No
8	Ulnar paraesthesia	Ulna and radius*	Reduced sensation ulnar nerve distribution	RHSC	Yes
8	Median paraesthesia	Supracondylar*	NVI	External	No
12	Median paraesthesia	Radial*	Reduced sensation median nerve distribution noted	RHSC	Yes
9	Ulnar palsy	Elbow dislocation	Nil	External	No
7	Median paraesthesia	Ulna and radius*	Reduced sensation median nerve distribution noted	RHSC	Yes
6	Ulnar paraesthesia	Ulna and radius*	NVI	External	No
9	Ulnar neurapraxia	Supracondylar*	Reduced ulnar nerve motor function and sensory loss	RHSC	Yes

*Fracture.
NVI, neurovascularly intact; RHSC, Royal Hospital for Sick Children.

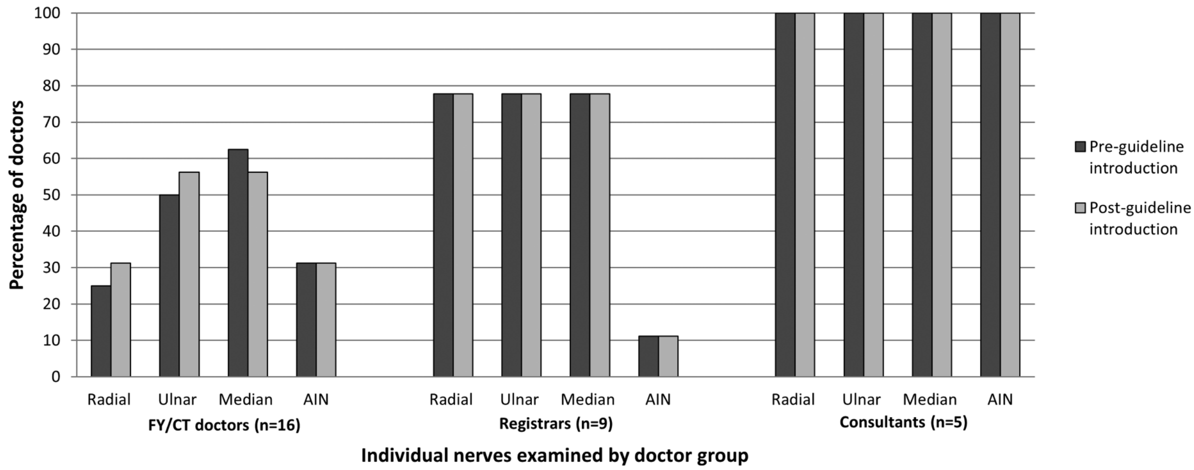

Figure 2 Percentage of doctors describing a neurological examination adequately assessing individual nerve function on survey preguideline and postguideline introduction. AIN, anterior interosseous nerve; CT, core trainee; FY, foundation year.

demonstrated an associated increase in underlying knowledge of neurological examination. In particular, junior emergency doctors remained less able to describe an adequate examination for upper limb nerve assessment than their registrar or consultant colleagues. This would indicate that a guideline may impact on practice by encouraging a standardised assessment, regardless of knowledge and experience, but without necessarily enhancing full understanding.

The need to assess the AIN was also not recognised by the majority of junior emergency doctors, despite it being the most commonly injured nerve in humeral supracondylar fractures. Interestingly, up to a third of junior doctors still described an examination technique that would test AIN function as part of median nerve assessment. This suggests that nerve function can be assessed without having full knowledge of what is being tested. However, in cases where a neurological deficit is detected, it may be more difficult for junior medical staff to determine which nerves have been injured. This may result in less accurate documentation of neurological assessment as well as difficulties in communicating nerve injuries to specialist teams.

There are a number of limitations to our study. Data were collected by a different single reviewer preguideline and postguideline introduction, which may have resulted in reporting variability. To try and combat this, a standardised data collection sheet was used. The second reviewer was not informed of the study hypothesis at the time of data collection to minimise reporting bias. However, it is difficult to be certain they did not become aware of the hypothesis during the data collection period. It is possible that improvement in nerve injury detection between the two study periods may have been influenced by factors other than the guideline, such as external teaching or differences in experience of rotating ED doctors. Nonetheless, there was no evidence of improvement in ED medical staff knowledge about nerve examination between the study periods. We also included a control group (patients admitted from external hospitals) in the study. In this group, where the guideline was not implemented, there was no improvement in nerve injury detection suggesting any improvement in nerve injury detection resulted from the guideline itself.

The British Orthopaedic Association Standards for Trauma (BOAST) guideline highlights the importance of neurological examination in patients with limb injuries and emphasises clear documentation of this evaluation.[12] In the paediatric ED, nerve injuries associated with upper limb fractures may be missed due to difficulties with examination as well as inadequate assessment techniques. Our study shows that introduction of a simple guideline to paediatric EDs can significantly improve documentation of neurological examination and detection rates for fracture-associated nerve injuries.

Acknowledgements We would like to thank the ED staff at the Royal Hospital for Sick Children (Yorkhill), Glasgow for facilitating this project. In particular, we would like to thank the Clinical Lead for the ED, Scott Hendry, and the other ED consultants for supporting the use of the guideline ('rock, paper, scissors, OK') and allowing us to study its impact in the department.

Contributors AGM conceived of the idea for the guideline and the project. AGM, JGR and JSH developed the guideline and contributed to the design of the project. All authors assisted with collection of the data. AGM wrote the first draft. All authors revised/rewrote the manuscript and discussed this at revisional stages. The final manuscript was read and approved by all authors. JSH is the guarantor.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The lead author would be happy to supply the raw data from both quality improvement cycles on request by email.

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EMJ

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Emerg Med J 2016 33: 273-277 originally published online February 15, 2016
doi: 10.1136/emermed-2014-204414