The utilisation of intraosseous infusion in the resuscitation of paediatric major trauma patients

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Accepted 12 November 2004

Summary Intraosseous lines are a reliable and rapid tool for obtaining vascular access in emergency situations, particularly in children. Their use is recommended when intravenous access cannot be easily secured and there is a need for fluid or pharmacological resuscitation. Training in this technique is included in the Advanced Trauma Life Support (ATLS) and Advanced Paediatric Life Support course (APLS) provider courses. The objective of this study is to analyse the national use of intraosseous lines in paediatric trauma in England and Wales. Data has been collected from the Trauma Audit and Research Network (TARN) group longitudinally over 14 years from 1988 to 2002. From 23,489 paediatric trauma cases, intraosseous lines were used in only 129 patients. Compared with the remainder of the paediatric data, we found that these were the younger (1–6 years), more severely injured patients (higher ISS, lower GCS, higher head, thorax, and abdominal AIS). The mortality of these patients was high at 64% compared with 4% overall. IO line use was greater in general than in Paediatric hospitals, perhaps due to good intravenous access skills in paediatric centres. We recommend that intraosseous line use should be a skill available to everybody involved in paediatric trauma resuscitation, particularly those who may not have refined paediatric intravenous cannulation skills.

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Introduction The intraosseous route of vascular access was initially discovered over 60 years ago,5,9,19 and initially used principally on adults as well as on children. Its use declined with the advent of simple to use and reliable intravenous cannulae.19 Although intraoss-
paediatric resuscitation in 2001 suggested revision of the 1992 JAMA guidelines “In children 6 years of age or under, intraosseous vascular access should be established, if reliable venous access cannot be achieved within three attempts or 90 s, whichever comes first.” to “Intraosseous access should be established, if reliable venous access cannot be achieved in the presence of cardiac arrest or decompensated shock (Class 2b). In the newborn, intraosseous access should be established if umbilical venous access cannot be established.” Abe et al. found that intraosseous access was faster than umbilical catheterisation in the newborn.

There is a documented low complication rate associated with intraosseous access. The commonest reported complication being osteomyelitis, probably related to poor sterile technique in an emergency setting. The risk of this is suggested to be around 0.6%. Fungal osteomyelitis has also been reported. Other reported complications are fracture, compartment syndrome, and failure to infuse fluid due to needle bending or clogging with marrow. Suspicion of non-accidental injury has also been reported when post trauma children have abnormal radiographs at a later presentation to hospital as a result of the healing cortical defect. Most of the reported complications can be related to poor insertion technique, poor asepsis or using the access for too long. Reassuringly, there is no reported growth disturbance in human series and in animal studies where high rates of infusion and the infusion of hyper-osmotic solutions have not produced marrow changes at 6 weeks. Training in the use of intraosseous access is simple, and studies demonstrate that becoming proficient in reliably and rapidly placing an intraosseous needle is a rapid process. In some regions, pre hospital staff has been trained and can perform this technique when necessary. There are a number of needle types available, these include specially designed intraosseous access needles, a Jamshidi marrow aspiration needle or a simple butterfly or spinal needle. A variety of placement sites are also possible, with the proximal tibia being the most favoured, followed by the distal tibia, the distal femur, sternum, distal radius, os calcis or shoulder. Theoretically any safe superficial bone particularly in children can be used. This method should not be used in an already injured limb. The large range of fluids and drugs that have been found to be safe for intraosseous infusion enhances this flexibility.

As intraosseous vascular access is simple, rapid, safe and can be used in the shocked child with reported ease it is not surprising that it is taught on the Advanced Paediatric Life Support course (APLS) and Advanced Trauma Life Support student courses. This is a rarely used technique and it is not entirely surprising that it has not been seen in use in our paediatric orthopaedic unit. We were interested to find out how often and in what circumstances IO lines were used in the overall trauma setting. In order to assess the use of this rarely seen technique, a large database was required to generate adequate numbers to study.

Data and methods

We utilised the Trauma Audit and Research Network (TARN) to acquire data. This network has collected data since 1988 on major trauma throughout England and Wales by retrospective analysis of patient records. Patients included are any trauma related mortality or any case requiring 72 or more hours of in patient hospital care. From the extensive database, we requested information on the paediatric cases, in which intraosseous line use had been documented, and then further information on the:

- age;
- injury severity score (ISS);
- Glasgow Coma scale (GCS);
- Abbreviated Injury score (AIS);
- mortality;
- fluid volume infused during resuscitation;
- general hospital or paediatric hospital.

We then analysed the patients in whom IO access had been used and compared them with the remainder of the paediatric trauma patients in the network. Inter quotient ratios (IQR) and 95% confidence intervals (95% CI) were implemented to demonstrate significant statistical differences.

Results

A total of 23,489 paediatric trauma cases were included in the England and Wales TARN database from 1988 to 2003. From these, only 129 (0.55%) episodes of intraosseous line use were recorded. From the remainder, there were 13,488 cases where the IO line use box was not marked on the data audit form, and in the remaining 9872 clear documentation that no IO line had been used. In analysing the results, it is clear that the no IO line use, and the no IO line documentation groups are almost identical. We also presume that IO line use is likely to be documented in the notes, as it is an uncommon
procedure to perform, and therefore to be noted by
the audit data collection. We have for these reasons
considered the no IO line, and the no IO documenta-
tion groups together in the results analysis as no IO
line (see Table 1 for detail).

Age

The IO patients were a younger group than the no IO
group median 3 years (IQR 1–6) compared with 9
years (IQR 4–13).

Gender

There is no difference in the male preponderance in
the groups.

Trauma

The higher energy trauma sustained by the IO group
is reflected in the RTA% at 59% for the IO group
compared with 42% for the no IO group, the GCS of 5
in the IO group compared with 15 in the no IO group,
and the significantly higher proportion of high
abbreviated injury scores (AIS3+) for:

- The head 59% compared with 27%;
- The thorax 25% compared with 5%;
- The abdomen 14% compared with 3%.

There were a lower proportion of AIS3+ limb
patients in the IO line group 19% (13–26%, 95% CI)
compared with 36% (35–37%, 95% CI).

Intravenous access and fluids

There was no difference demonstrated between the
groups in the placement of intravenous access, or in
the volumes of fluid infused during resuscitation.
The timing of intravenous cannulation is not known.

Paediatric hospitals

Fourteen percent of the no IO line group were
reated at a paediatric hospital, compared with
8% of the IO line group. This suggests a lower
proportional use of IO lines in paediatric hospitals,
and a higher proportional use in general hospitals.
The case mix is however not known here.

Mortality

The mortality of the IO line group is considerably
higher than the no IO group at 64% compared with
4%.

Discussion

The intraosseous method of systemic access is a
useful tool in the paediatric arrest or trauma situa-
tion. The literature contains a number of articles
praising and recommending the method, along with
a few reporting uncommon complications. A single
centre retrospective study\textsuperscript{[11]} demonstrated a similar
pattern of use to that which we found. They had a
mixed population of trauma and arrest patients, the
ISS in the trauma patients was high at 35.8 (4–75)
and the mortality high at 74% (17/23). Twenty-five

\textbf{Table 1} Results

<table>
<thead>
<tr>
<th></th>
<th>Overall total N</th>
<th>IO line, 129</th>
<th>IO line no document, 13,488</th>
<th>No IO line, 9872</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age (IQR)</td>
<td>3 (1–6)</td>
<td>9 (4–13)</td>
<td>9 (5–13)</td>
<td></td>
</tr>
<tr>
<td>% Male (95% CI)</td>
<td>63 (50–67)</td>
<td>67 (66–68)</td>
<td>68 (68–69)</td>
<td></td>
</tr>
<tr>
<td>% In RTA (95% CI)</td>
<td>59 (50–67)</td>
<td>42 (41–43)</td>
<td>42 (41–43)</td>
<td></td>
</tr>
<tr>
<td>% Missing 1st GCS data</td>
<td>31</td>
<td>19.7</td>
<td>14.1</td>
<td></td>
</tr>
<tr>
<td>% Head AIS3+ (95% CI)</td>
<td>59 (50–67)</td>
<td>27 (26–27)</td>
<td>21 (20–22)</td>
<td></td>
</tr>
<tr>
<td>% Thoracic AIS 3+ (95% CI)</td>
<td>25 (17–23)</td>
<td>5 (5–6)</td>
<td>4 (4–5)</td>
<td></td>
</tr>
<tr>
<td>% Abdo AIS 3+ (95% CI)</td>
<td>14 (8–20)</td>
<td>3 (2–3)</td>
<td>3 (2–3)</td>
<td></td>
</tr>
<tr>
<td>% LimbAIS3+ (95% CI)</td>
<td>19 (13–26)</td>
<td>36 (35–37)</td>
<td>43 (42–44)</td>
<td></td>
</tr>
<tr>
<td>% IV Line (peripheral or central in ED or pre-hospital) (95% CI)</td>
<td>82 (75–89)</td>
<td>84 (84–85)</td>
<td>84 (83–83)</td>
<td></td>
</tr>
<tr>
<td>Median fluid infused (IQR)</td>
<td>475 (0–500)</td>
<td>380 (0–1000)</td>
<td>0 (10–500)</td>
<td></td>
</tr>
<tr>
<td>% Received at paediatric hospital (95% CI)</td>
<td>8 (5–12)</td>
<td>15 (15–16)</td>
<td>13 (13–14)</td>
<td></td>
</tr>
<tr>
<td>% Mortality (95% CI)</td>
<td>64 (54–74)</td>
<td>4 (4–4)</td>
<td>3 (3–3)</td>
<td></td>
</tr>
<tr>
<td>Mortality (N)</td>
<td>60</td>
<td>248</td>
<td>362</td>
<td></td>
</tr>
</tbody>
</table>
of the 27 patients in their series were 7 years or younger with a mean age of 2.9 years (3 months to 10 years). In our results, the mean age of 3 years (IQR 1–6) for IO line use fits with the common guidelines to use this method in children of under 6 years, and is also a likely indication that these are the children in whom intravenous access is most difficult, especially when shocked. The cases where IO lines were used had evidently been involved in major trauma generally. The RTA, ISS, GCS, and AIS3+ demonstrate this for head, thorax and abdomen scores. The patients with this degree of trauma are those who will be in a severe shocked state and require vascular access rapidly in circumstances where venous access will be difficult. A high limb AIS is less often associated with IO line use. Many patients who have isolated significant limb injuries require hospital admission, but do not develop severe shock, and therefore do not require IO line placement for aggressive fluid resuscitation. The substantial mortality associated with IO line use is most likely to be the result of the severity of injury in those patients in which it is used, as demonstrated in our results. The technique itself is not likely to like contributing to the mortality. It is interesting that IO use appears to be less common in paediatric centres than in general hospital settings. It might have been expected that paediatric specialists would have greater training and experience at IO access, but perhaps their more refined intravenous access skills preclude the need for IO access. It seems that those in general centres who may only rarely cannulate children are those who use IO line skills in an emergency situation. This study has the benefit of large numbers, but the data collection is based on retrospective notes analysis, and can be incomplete as seen in the no IO data group, and the first GCS data missing patients. We do feel that the data are useful to give an overview of the use of IO lines in paediatric trauma resuscitation.

In conclusion, we found that IO line use is in the young and the most severely injured children. The mortality of these patients is very high. IO line use is more prevalent in general hospitals than in paediatric hospitals, and we suggest that this is an important area at which to aim training of this safe, simple, and effective paediatric resuscitation tool.

Acknowledgments to the TARN Participating Hospitals since 1989

Addenbrooke’s Hospital Cambridge; Heatherwood & Wexham Park Hospital Slough; Rotherham District General Hospital; The Princess Royal Hospital Shropshire; Airedale General Hospital Yorkshire; Hillingdon Hospital Middlesex; Royal Albert Edward Infirmary Wigan; Torbay Hospital Devon; Arrowe Park Hospital Merseyside; Hinchingbrooke Hospital Cambridgeshire; Royal Berkshire Hospital Reading; Trafford General Hospital Manchester; Ashford General Hospital London; Homerton Hospital London; Royal Bolton Hospital Farnworth; University Hospital Lewisham London; Atkinson Morley’s Hospital London; Hope Hospital Salford; Royal Cornwall Hospital Truro; University Hospital of Hartlepool Barnsley; District General Hospital Yorkshire; Huddersfield Royal Infirmary Royal Devon & Exeter Hospital University Hospital of North Staffordshire; Basildon Hospital Essex; Hull Royal Infirmary North Humber-side; Royal Gwent Hospital Newport; University Hospital of North Tees; Cleveland Bassetlaw Hospital Nottinghamshire; Ipswich Hospital Suffolk; Royal Hallamshire Hospital; Sheffield University Hospital of Wales; Cardiff Bedford Hospital; James Cook University Hospital Cleveland; Royal Hampshire County Hospital Winchester; University Hospital, Aintree Liverpool Birmingham Heartlands Hospital; James Paget Hospital Norfolk Royal Lancaster Infirmary; Walton Centre for Neurology Liverpool Blackburn Royal Infirmary Lancashire; Jersey General Hospital; Royal Liverpool Childrens Hospital (Alder Hey); Wansbeck General Hospital; Northumberland Blackpool Victoria Hospital; John Coupland Hospital; Royal Liverpool University Hospital; Warrington Hospital Cheshire; Booth Hall Children’s Hospital Manchester; John Radcliffe Hospital Oxon; Royal London Hospital; Warwick Hospital Warwick; Bradford Royal Infirmary Yorkshire; Kent & Canterbury Hospital; Royal Manchester Children’s Hospital Pendlebury; Waterford Regional Hospital Ireland; Bristol Royal Infirmary Kent & Sussex Hospital; Royal Oldham Hospital; Watford General Hospital Herts; Bromley Hospital Kent; Kettering General Hospital Northamptonshire; Royal Preston Hospital; West Cumberland Hospital Cumbria; Broomfield Hospital Essex; Kings College Hospital London; Royal Shrews bury Hospital Shropshire; West Middlesex University Hospital; Burnley General Hospital; Kings Mill Hospital Nottinghamshire; Royal Surrey County Hospital; West Wales General Hospital Dyfed; Calderdale Royal Hospital Halifax; Leeds General Infirmary; Royal Sussex County Hospital Brighton; Weston General Hospital Avon; Cheltenham General Hospital; Leicester Royal Infirmary; Royal United Hospital Bath; Weymouth & District Hospital Dorset; Chesterfield & Nth Derbyshire Royal Hospital; Leigh Infirmary; Royal Victoria Hospital, Belfast N Ireland; Whipp’s Cross Hospital London; Chorley District General Hospital; Leighton Hospital Cheshire; Royal
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