​​​​**Pre-operative vascular assessment of the perfused, pulseless supracondylar fracture – a systematic review**

**Introduction**

There is a large body of evidence that considers distal perfusion following supracondylar humeral fracture [1–3](https://paperpile.com/c/AyiZEF/bVVK5+PmuXP+MbIbm). There is, however, lack of consensus about the evaluation of the pulseless limb, which may result in delays in management that compound an ischaemic injury. The British Orthopaedic Association (BOA) recommends the documentation of radial pulse and digital capillary refill time on presentation and before surgical treatment with deteriorating perfusion used as an indication for immediate vascular assessment, however a definition of ischaemia is lacking [4](https://paperpile.com/c/AyiZEF/0fhrM). The American Academy of Orthopaedic Surgeons (AAOS) used a voting panel to recommend that a perfused hand is one that is warm, pink, with a capillary refill <3 seconds, without a distal pulse [5](https://paperpile.com/c/AyiZEF/Bwo7M).

This review aims to evaluate the available literature to explore the pre-operative assessment of perfusion in supracondylar fractures without a distal pulse and identify possible clinical implications associated with inaccurate assessment.

**Materials and methods**

A systematic literature review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Figure 1). This was prospectively registered on the International Prospective Register of Systematic Reviews (PROSPERO).

Pubmed, MEDLINE, EMBASE and The Cochrane Library were explored in June 2022 using the search terms (pulseless OR dysvascular OR ischaemic OR perfused OR vascular injury) AND supracondylar AND (fracture OR fractures). The search was not limited by year of publication, journal type, or level of evidence. The bibliographies of all articles that were included were cross referenced for further relevant studies.The study included English language articles reporting patients under the age of 18 years with an isolated supracondylar humeral fracture, with documentary evidence of an evaluation of the pre-operative vascular status demonstrating perfusion.

Two authors (TH, GC) reviewed the abstracts of all papers that corresponded to the search terms and assessed them for inclusion according to the above criteria, with disagreement resolved by senior author (YG) review. Full texts were obtained for all articles that were considered suitable for more detailed evaluation andtype of publication, number of cases, pre-operative vascular assessment, seniority of assessor, time to theatre, treatment undertaken and vascular outcomes were recorded. The risk of bias was assessed according to the Coleman Methodology score[6](https://paperpile.com/c/AyiZEF/WRvxs)and all data were pooled and descriptive data analysis performed.

**Results**

The initial literature search identified 573 articles suitable for further study, 25 met the inclusion criteria and included 504 patients with a perfused, pulseless extremity following supracondylar humeral fracture. These were all case series and methodological analysis was generally poor to moderate (Table 1) with a mean Coleman score of 28 (range 5-67).

**Study characteristics**

**Pre-operative vascular assessment** (Table 2).

Skin colour was used to assess perfusion in 23/25 studies[7–29](https://paperpile.com/c/AyiZEF/n7BmC+XcS4T+o0UgX+at3xN+O3tLP+CIJXd+kfbqm+ue9eJ+nNk6s+zUqJz+jBp61+mQteV+DsUZb+1YknT+jP5Fq+8aIzm+P17U2+OWkw4+By5WU+Smjjr+rFm4v+hqdCD+MIXVv) but none provided an objective classification of skin colour, with “pink” used to classify a perfused hand in 20/25 studies [7–13,15–19,21–24,26–29](https://paperpile.com/c/AyiZEF/MIXVv+hqdCD+rFm4v+n7BmC+8aIzm+XcS4T+Smjjr+jP5Fq+o0UgX+at3xN+O3tLP+OWkw4+CIJXd+kfbqm+nNk6s+jBp61+P17U2+mQteV+DsUZb+zUqJz). Skin temperature was used in 16/25 studies[8–12,15,21–30](https://paperpile.com/c/AyiZEF/XcS4T+o0UgX+at3xN+O3tLP+OWkw4+CIJXd+nNk6s+P17U2+jP5Fq+Ed6z6+8aIzm+MIXVv+hqdCD+rFm4v+Smjjr+By5WU) but none reported an objective method of assessment. Capillary refill time (CRT) was used in 13/25 studies[8–10,12–16,23,24,27,29,31](https://paperpile.com/c/AyiZEF/XcS4T+o0UgX+at3xN+OWkw4+CIJXd+kfbqm+ue9eJ+nNk6s+zUqJz+P17U2+MIXVv+rFm4v+Rfcmx) but only 5/25 reported a cut off time representing normal perfusion (<2 seconds[9,13](https://paperpile.com/c/AyiZEF/o0UgX+kfbqm), <3 seconds [27,29,31](https://paperpile.com/c/AyiZEF/Rfcmx+MIXVv+rFm4v)) It was not clear in any of the studies whether the contralateral limb was used as a baseline comparator. Usman et al.[24](https://paperpile.com/c/AyiZEF/OWkw4) reported a mean CRT of 3s (+/-2s) in their pink, warm, pulseless cohort.

Peripheral oxygen saturation (SaO2) was measured in 6/25 studies[12,16,17,23,24,30](https://paperpile.com/c/AyiZEF/OWkw4+CIJXd+zUqJz+jBp61+P17U2+Ed6z6). Ramesh et al.[17](https://paperpile.com/c/AyiZEF/jBp61) used peripheral oxygen saturation waveforms as confirmation of the presence of a pulse. Usman et al.[24](https://paperpile.com/c/AyiZEF/OWkw4) reported mean SaO2 of 85% (+/-3%) in their pink warm pulseless cohort but the other studies did not provide further technical details.

Pre-operative US was used in 14/25 studies[7–9,11–15,17,19,21–23,30](https://paperpile.com/c/AyiZEF/n7BmC+XcS4T+o0UgX+O3tLP+CIJXd+kfbqm+ue9eJ+nNk6s+jBp61+P17U2+DsUZb+jP5Fq+Ed6z6+8aIzm) Doppler in 14/25 and Duplex in 5/25[7,15,21,22,30](https://paperpile.com/c/AyiZEF/8aIzm+Ed6z6+jP5Fq+nNk6s+n7BmC) to either confirm the presence of a pulse, determine pressures, or assess anatomical disturbances to the vessels including compression, entrapment, or the presence of thrombus. Angiography was used selectively in 2/25 studies,[11,13](https://paperpile.com/c/AyiZEF/O3tLP+kfbqm) in cases in whom there was concern about vascularity in the pre-operative period, but the criteria for use was not clear in either study. The seniority of the clinical decision maker (Table 3) was recorded in 3/25 studies[8,14,18](https://paperpile.com/c/AyiZEF/XcS4T+ue9eJ+mQteV) and each identified a Consultant (Attending).

**Time to management of vascular injury**

Temporal parameters (Table 3) were available in 13/25 studies[7,9,12,14,16–19,22,23,30](https://paperpile.com/c/AyiZEF/n7BmC+o0UgX+CIJXd+ue9eJ+zUqJz+jBp61+P17U2+mQteV+DsUZb+Ed6z6+8aIzm) but 3 reported only “early”[20](https://paperpile.com/c/AyiZEF/1YknT) or “prompt”[21](https://paperpile.com/c/AyiZEF/jP5Fq) or “emergently” [26](https://paperpile.com/c/AyiZEF/Smjjr) as a description for time to theatre, without further clarification. The time from either injury or presentation to theatre ranged from 90 minutes to 12 hours and 6/25 reported an average delay of < 3 hours. It was not possible to combine this to produce an average/range due to the heterogeneity of the data.

**Management of vascular injury**

Vascular intervention either in the form of open exploration or angiographic techniques was reported in 92 cases in 17 studies[8,11–13,15,16,18–25,28,30,31](https://paperpile.com/c/AyiZEF/XcS4T+O3tLP+OWkw4+CIJXd+kfbqm+nNk6s+zUqJz+P17U2+mQteV+DsUZb+1YknT+jP5Fq+Ed6z6+8aIzm+hqdCD+Rfcmx+By5WU) and represented 18% of all cases (Table 3). The indications for vascular exploration, vascular findings and vascular interventions are summarised in Tables 4, 5, and 6.

The most common indications were either a persistently absent pulse after reduction, or abnormal angiography and the most common abnormalities were an entrapped or tethered artery at the fracture site. The most common vascular intervention was open release of the entrapped artery.

**Assessment of final vascular status**

A clinical vascular examination at follow up was performed in 18/25 studies[7,9–17,19–21,23–25,28,30](https://paperpile.com/c/AyiZEF/n7BmC+o0UgX+at3xN+O3tLP+OWkw4+CIJXd+kfbqm+ue9eJ+nNk6s+zUqJz+jBp61+P17U2+DsUZb+1YknT+jP5Fq+Ed6z6+By5WU+hqdCD) and generally involved palpation of the radial/ulnar/brachial pulse and documentation of clinical signs of ischaemia or compartment syndrome. A specific vascular outcome screening tool was not described but Paediatric Outcomes Data Collection Instrument (PODCI) was used in 2/25[8,14](https://paperpile.com/c/AyiZEF/XcS4T+ue9eJ) and quick Disabilities of the Arm, Shoulder and Hand Score (qDASH) in one[8](https://paperpile.com/c/AyiZEF/XcS4T).

Follow-up US was used in 7/25 studies[7,10,14,15,19,20,30](https://paperpile.com/c/AyiZEF/n7BmC+at3xN+ue9eJ+nNk6s+DsUZb+Ed6z6+1YknT), usually for persistent absence of distal pulses to assess the patency of the brachial artery and adequacy of collateral circulation. Static blood pressure or wrist/brachial pressure indices were used in 4/25 studies[13,14,20,30](https://paperpile.com/c/AyiZEF/kfbqm+ue9eJ+1YknT+Ed6z6)and Magnetic Resonance Angiography (MRA) was used in 1/25 studies[20](https://paperpile.com/c/AyiZEF/1YknT).

**Vascular outcome**

Follow-up ranged from 24 hours to 8.4 years, with 5 studies not reporting length of follow up[11,25–27,29](https://paperpile.com/c/AyiZEF/O3tLP+MIXVv+rFm4v+Smjjr+By5WU)and 6 not fully reporting vascular outcome[18,22,26,27,29,31](https://paperpile.com/c/AyiZEF/mQteV+8aIzm+Rfcmx+MIXVv+rFm4v+Smjjr). Persistent vascular abnormalities were reported at final follow up in 6 studies[8,10,14,20,21,30](https://paperpile.com/c/AyiZEF/at3xN+ue9eJ+1YknT+Ed6z6+XcS4T+jP5Fq)andnormal vascular function in 13.

Cambon-Binder et al.[10](https://paperpile.com/c/AyiZEF/at3xN)reported 1 patient with no pulse after 7 weeks in a series of 18 individuals. US demonstrated a thrombosed brachial artery but with good forearm flow. Scannell et al.[14](https://paperpile.com/c/AyiZEF/ue9eJ)reported a Duplex US study involving 20 patients. Brachial artery occlusion was demonstrated in 5 patients, 3 of which had associated abnormalities of wrist/brachial pressure indices, one with brachial artery stenosis and one with cold intolerance.

Sabharwal et al.[20](https://paperpile.com/c/AyiZEF/1YknT) reported the results of MRA in a series of 12 patients and identified 4 with brachial artery occlusion/stenosis.

Luria et al.[30](https://paperpile.com/c/AyiZEF/Ed6z6) reported 1 patient with an atherosclerotic plaque, without impairment of flow at the site of intimal arterial tear repair in a series of 24 patients investigated with Duplex US.

Ernat et al.[8](https://paperpile.com/c/AyiZEF/XcS4T), reported the outcome of 146 patients, of which 14% had abnormal vascular exams at presentation. It was demonstrated that patients with symmetric palpable pulses at presentation had higher PODCI pain and comfort and qDASH scores than those with non palpable pulses.

Grant et al.[21](https://paperpile.com/c/AyiZEF/jP5Fq) reported 2 patients who developed ischaemia within 1-3 days of closed reduction and percutaneous pinning. Both patients underwent surgical exploration for entrapment of the artery within the fracture and required fasciotomies with mild motor weakness and finger contracture in one patient at 1 year follow up.

**Discussion**

Paediatric supracondylar humeral fractures are associated with absence of distal pulse in up to 19%[32](https://paperpile.com/c/AyiZEF/uhmbZ) of cases and distinguishing between a well perfused limb and a limb with evolving ischaemia can be challenging[32](https://paperpile.com/c/AyiZEF/uhmbZ), and can have a significant impact on clinical decision making[33](https://paperpile.com/c/AyiZEF/wQTS). This systematic review considered 504 patients from 25 studies to evaluate the pre-operative assessment of vascularity in fractures that presented without a palpable distal pulse. This demonstrated that the available literature is heterogenous with a range of assessment strategies, treatment algorithms and outcome assessments. There is clearly a spectrum of dysvascularity and it is important to be able to differentiate those cases that are associated with peripheral ischaemia. This requires accurate clinical assessment to identify limbs at risk to allow prompt decision making and operative intervention whenever necessary.

Skin colour is frequently used as a surrogate marker of perfusion but this was not objectively defined in any of the studies. Commonly used terms include “pink” and “white”, but as this is limited to specific skin tones it is a subjective and potentially unreliable measure, however this was not specifically studied in the papers in our review. Zhu *et al* attempted to develop a scoring system for limb perfusion in children with limb fractures but did not include practical details about how to use this in an objective and reproducible manner. This used skin colour as a key marker and a poorly perfused limb was described as being ‘more pale’ than the contralateral side[34](https://paperpile.com/c/AyiZEF/ZG49P).

Skin temperature is an indirect assessment of vascularity but this is subjective and is also affected by systemic and environmental factors. None of the studies reported an objective assessment of skin temperature but this has been previously used in the development of a scoring system for limb perfusion in children with limb fractures. Zhu *et al* suggested that a difference of >/= 3°C between the injured and contralateral was a marker of poor perfusion[34](https://paperpile.com/c/AyiZEF/ZG49P). The recommendations from this study should be approached cautiously as there were methodological deficiencies, including absence of detail on the tool that was used to measure skin temperature and imprecise definition of a poorly perfused limb.

Assessment of perfusion by comparing capillary refill time to the uninjured limb is in common clinical use. It is easy to perform, requires no more than basic training and 2 of the studies suggested a </=2 second cut off time [9,13](https://paperpile.com/c/AyiZEF/o0UgX+kfbqm), and 3 studies a <3 second cut off [27,29,31](https://paperpile.com/c/AyiZEF/MIXVv+rFm4v+Rfcmx). Monteerarat et al used the finger pulp as an alternative to the nail bed and reported an optimal cut off value of 3 seconds[35](https://paperpile.com/c/AyiZEF/ijHMV). The American Academy of Orthopaedic Surgeon Appropriate Use Criteria (AAOS AUC) guidelines for supracondylar fracture also support a cut off value 3 seconds[36](https://paperpile.com/c/AyiZEF/2cz3I). British Orthopaedic Association Standards for Trauma (BOAST) guidelines support the use of CRT in assessment, but without reference to an objective cut off[4](https://paperpile.com/c/AyiZEF/0fhrM).

Pulse oximetry was used in 6/25 studies in this review. It has also been used for objective assessment of hand perfusion[37](https://paperpile.com/c/AyiZEF/xdQ8m) and arterial waveforms have been shown to be comparable to US Doppler flow waveforms[38](https://paperpile.com/c/AyiZEF/WJX9G). This, in addition to absolute pO2, is valuable in the assessment of limb perfusion. Pre-operative US was reported in 14/25 of the studies and was used to confirm the presence of a pulse, measure pressure indices or used duplex modes to assess the anatomy of a vascular injury. The exact values that might affect management are as yet unknown and will need to be subject to further study.

Angiography is an invasive investigation in the evaluation of limb perfusion and also involves exposure to ionising radiation. Techniques that do not involve X-rays including MRA, are painful and therefore impractical in a young child in an emergency situation and the role suggested by this review was unclear.

Mangat et al. reported a relationship between a pre operative median nerve/AIN deficit and vascular entrapment/tethering[18](https://paperpile.com/c/AyiZEF/mQteV), and suggested that patients with this pattern of injury should have open exploration of the artery. Khan et al. supported this in their case series demonstrating entrapment of the neurovascular bundle in the 2 patients with concomitant nerve injury[28](https://paperpile.com/c/AyiZEF/hqdCD). There were no other papers in our systematic review that considered this and although a useful reminder, does not provide sufficient evidence to mandate open vascular exploration in such cases. Mahdy et al. commented that a brachialis rupture could be an indicator for brachial artery injury, but is the only paper in the series to look at this and in small numbers (4 cases)[22](https://paperpile.com/c/AyiZEF/8aIzm).

The seniority of the clinician was discussed in 3/25 and in these studies, a consultant or equivalent was involved in deciding urgency of operative intervention. Many of these patients present out of hours[39](https://paperpile.com/c/AyiZEF/7eNWA) and the identity and seniority of the clinician is unclear in the majority.

The overall quality of the available date is, therefore, insufficient to make any evidence based recommendation.

Time to theatre was reported in 13/25, with 6/13 reporting definitive management within 3 hours of either injury or presentation but data is insufficient to support any recommendations.

BOAST guidelines[4](https://paperpile.com/c/AyiZEF/0fhrM) suggest that urgent surgery is indicated when there is an absent radial pulse, clinical signs of impaired perfusion of the hand and digits, open injury or threatened skin viability. All cases in this series presented with an absent radial pulse and therefore should be treated urgently according to these recommendations. A recent systematic review evaluating the management of paediatric pulseless supracondylar fractures also supports the urgent surgical reduction and pinning of these injuries[40](https://paperpile.com/c/AyiZEF/ikGyz).

This review has demonstrated that the clinical assessment of the vascular consequences of this injury is varied and imprecise. Exploration and treatment of an arterial injury was necessary in 18% of cases (92/504) and although this may be subject to publication bias, it indicates that the pulseless perfused limb is not a benign clinical entity.

A dependable strategy is therefore required to detect evolving ischaemia, using reliable clinical parameters. Whilst modalities such as US and angiogram are useful for more detailed descriptions of vascular injuries, they are resource intensive and do not necessarily provide information that is sufficiently reliable to warrant their routine use. This review has identified deficiencies in the objective assessment of these injuries including a lack of cut-off values, comparison to the uninjured contralateral limb, and decision making pathways. Incorporation of more objective data into our clinical assessment will hopefully provide better observational data going forwards to improve our understanding of perfusion assessment in the future.

Based on this review we recommend:

1. Colour and CRT should be used with a caveat that this may be difficult to interpret in a non-Caucasian population. We suggest that a cut off value <3s is pragmatic, albeit unevidenced and should be compared to the uninjured limb and clearly documented.

2. SaO2 could be measured compared to the uninjured limb and the findings documented. This may have more of a role initially in a research setting.

3. Vascular assessment should be repeated frequently to detect early deterioration in limb perfusion, particularly in patients with expectant management of the fracture.

4. Decisions should be made by an experienced clinician, preferably a consultant.

5. A decision making pathway (based on an interpretation of national guidelines) should be locally agreed with an emphasis on training and escalation to a senior decision maker with appropriate experience, and prospectively compared to long term outcomes of limb function and perfusion.

**Conclusion**

The vascular assessment of the pulseless supracondylar fracture is variable, with few objective criteria being used to define perfusion. The evidence base for decision making is limited in quality and further research is required. We recommend incorporating the suggested objective assessment criteria outlined at this review and that these are performed frequently to detect an early deterioration of limb perfusion, with senior input to management decisions. We also recommend that management decisions are made with input from individuals with appropriate experience in the management of this important clinical scenario.

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**Table 1 - Study Characteristics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Author (year) | Follow up (mean unless otherwise stated) | Number of patients | Average Age (years) | Coleman Score |
| Emanuelli (2021) |  | 23 | 3-12 | 19 |
| Khan (2021) | 3 months | 8 | 7 | 5 |
| Tzatzairis (2021) |  | 5 | 1-16 | 5 |
| Xie (2021) | 4.5 years | 13 | 6 | 49 |
| Mahdy (2021) | 24 hours | 18 | 5.5 | 9 |
| Ernat (2020) | 87 days | 9 | 6.8 | 53 |
| Shore (2019) |  | 60 | 6.7 | 15 |
| Grant (2019) | 1 year | 4 | <18 | 5 |
| Delniotis (2018) | 1 year | 20 | 6.5 | 42 |
| Cambon-Binder (2018) | 3.5 years | 18 | 7 | 40 |
| Tunku-Naziha (2017) | Not reported | 7 | 8.5 | 20 |
| Usman (2017) | 6 months | 34 | 9 | 14 |
| Louahem (2016) | 8.4 years | 63 | 7.5 | 39 |
| Wegmann (2014) | 3.5 years | 36 | 6.5 | 25 |
| Scannell (2013) | 20 months | 20 | 6.9 | 67 |
| Valentini (2013) | 1-3 years | 8 | 8 | 20 |
| Soh (2013) | 24 months minimum | 37 | 3-12 | 28 |
| Ramesh (2011) | 36.6 months | 15 | 7.9 | 47 |
| Choi (2010) | 8 weeks (median) | 24 | 5.3 | 26 |
| Mangat (2009) | 6 months minimum | 19 | 3.8 | 17 |
| Korompillas (2009) | 34 months | 5 | 8.5 | 39 |
| Luria (2007) | 7 years | 11 | 6 | 27 |
| Ghasemzadeh (2002) | 1-3 years | 19 | <18 | 24 |
| Sabharwal (1997) | 31 months | 13 | 6.5 | 30 |
| Garbuz (1996) |  | 16 | 6.5 | 24 |

**Table 2 - Pre-Operative Vascular Assessment**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Author (year) | Pulse | US | Skin Colour | Skin temperature | Capillary Refill Time | SaO2 | Angiogram |
| Emanuelli (2021) | **+** |  | **+** | + | + |  |  |
| Khan (2021) | **+** |  | **+** | + |  |  |  |
| Tzatzairis (2021) | **+** |  | **+** | + | + |  |  |
| Xie (2021) | **+** | **+** | **+** |  |  |  |  |
| Mahdy (2021) | **+** | **+** | **+** | **+** |  |  |  |
| Ernat (2020) | **+** | **+** | **+** | **+** | **+** |  |  |
| Shore (2019) | **+** |  | **+** | **+** |  |  |  |
| Grant (2019) | **+** | **+** | **+** | **+** |  |  |  |
| Delniotis (2018) | **+** | **+** | **+** | **+** | **+** |  |  |
| Cambon-Binder (2018) | **+** |  | **+** | **+** | **+** |  |  |
| Tunku-Naziha (2017) | **+** | **+** | **+** | **+** |  |  | **+** |
| Usman (2017) | **+** |  | **+** | **+** | **+** | **+** |  |
| Louahem (2016) | **+** | **+** | **+** | **+** | **+** | **+** |  |
| Wegmann (2014) | **+** | **+** | **+** |  | **+** |  | **+** |
| Scannell (2013) | **+** | **+** | **+** |  | **+** |  |  |
| Valentini (2013) | **+** | **+** | **+** | **+** | **+** |  |  |
| Soh (2013) | **+** |  | **+** |  | **+** | **+** |  |
| Ramesh (2011) | **+** | **+** | **+** |  |  | **+** |  |
| Choi (2010) | **+** | **+** | **+** | **+** | **+** | **+** |  |
| Mangat (2009) | **+** |  | **+** |  |  |  |  |
| Korompillas (2009) | **+** | **+** | **+** |  |  |  |  |
| Luria (2007) | **+** | **+** |  |  |  | **+** |  |
| Ghasemzadeh (2002) | **+** |  |  |  | **+** |  |  |
| Sabharwal (1997) | **+** |  | **+** |  |  |  |  |
| Garbuz (1996) | **+** |  | **+** | **+** |  |  |  |

**Table 3 - Surgical treatment**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Author (year) | Time to theatre (mean and from presentation unless otherwise stated) | Seniority of decision maker | Treatment (Closed/open bony reduction and fixation) | Treatment (vascular intervention) |
| Emanuelli (2021) |  |  | 23 | 0 |
| Khan (2021) |  |  | 6 | 2 |
| Tzatzairis (2021) | <6 hours |  | 5 | 0 |
| Xie (2021) | 12 hours (1.5-48) |  | 13 | 0 |
| Mahdy (2021) | 1.44 hours (+/- 0.41) |  | 14 | 4 |
| Ernat (2020) |  | Consultant | 8 | 1 |
| Shore (2019) | “Emergently” |  | 60 |  |
| Grant (2019) | “Prompt” |  | 0 | 4 |
| Delniotis (2018) | 120 minutes (40-180) |  | 20 | 0 |
| Cambon-Binder (2018) |  |  | 18 | 0 |
| Tunku-Naziha (2017) |  |  | 0 | 7 |
| Usman (2017) |  |  | 16 | 18 |
| Louahem (2016) | 90 minutes (45-140) |  | 60 | 3 |
| Wegmann (2014) |  |  | 34 | 2 |
| Scannell (2013) | 7 hours (2-15) | Consultant | 20 | 0 |
| Valentini (2013) |  |  | 4 | 4 |
| Soh (2013) | All within 6 hours |  | 33 | 4 |
| Ramesh (2011) | 108 minutes (45-135) |  | 15 | 0 |
| Choi (2010) | 10.7 hours from injury (4-24) |  | 23 | 1 |
| Mangat (2009) | 6 hours (median, 3-29) | Consultant | 7 | 12 |
| Korompillas (2009) | 90 minutes (45-130) |  | 1 | 4 |
| Luria (2007) | 3 hours (40 minutes - 10 hours 15 mins) \* whole series \* |  | 4 | 7 |
| Ghasemzadeh (2002) |  |  | 17 | 2 |
| Sabharwal (1997) | “early” |  | 1 | 12 |
| Garbuz (1996) |  |  | 11 | 5 |

**Table 4 - Indications for vascular exploration**

|  |  |
| --- | --- |
| No pulse after reduction | 26 |
| Angiographic findings | 14 |
| Not defined | 8 |
| Absent signal on Dopper US pre reduction | 7 |
| Dysvascular after CRPP | 6 |
| Persistently absent pulse after reduction | 6 |
| No pulse 24 hours after CRPP | 4 |
| Absent pulse oximeter waveform after reduction | 4 |
| Lost pulse within 6 hours of reduction | 3 |
| CCDS severe spasm and displacement of artery | 3 |
| Compartment syndrome | 2 |
| Coexisting nerve injury | 2 |
| CCDS intimal-medial disruption with thrombosis | 1 |
| Unable to reduce fracture closed | 1 |
| Open fracture | 1 |

**Table 5 - Vascular Findings**

|  |  |
| --- | --- |
| Not Known | 20 |
| Entrapped/tethered artery | 25 |
| Entrapment and spasm | 9 |
| Intimal lesions | 7 |
| Thrombus | 6 |
| Spasm | 4 |
| Entrapment and thrombus | 3 |
| Contused segment | 2 |
| Compression | 2 |
| Kinking of artery | 2 |
| Haematoma | 2 |
| Transected/lacerated artery | 2 |
| Intimal-media disruption with thrombosis | 1 |
| Compartment syndrome | 1 |
| Entrapment, constriction and spasm | 1 |
| Tethered artery with small adventitial tear | 1 |
| Spasm with adventitial haematoma | 1 |
| Contusion, thrombosis and intimal tear | 1 |
| Entrapment and intimal tear | 1 |
| Thrombus and intimal flap | 1 |

**Table 6 - Vascular Interventions**

|  |  |
| --- | --- |
| Release of entrapped artery | 30 |
| Not known | 22 |
| Interposition vein graft | 8 |
| Thrombectomy | 4 |
| Artery decompression, release and 1% papaverine | 3 |
| Vein patch | 3 |
| Excision of contused segment, thrombectomy and primary repair | 2 |
| Excision of contused segment, thrombectomy and vein graft | 2 |
| End-end anastomosis | 2 |
| Release of tethered artery with fasciotomy | 2 |
| Haematoma decompression | 2 |
| Urokinase | 2 |
| Thrombectomy and interposition vein graft | 1 |
| Adventitial resection and papaverine | 1 |
| Segmental resection, thrombectomy and vein graft | 1 |
| Reduction of fracture | 1 |
| Embolectomy | 1 |
| Freeing of artery and haematoma release | 1 |
| Papaverine and fasciotomy | 1 |
| Exploration, arteriotomy and vein patch | 1 |
| Vein patch and urokinase | 1 |