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Review

Analgesic Techniques for Distal Radius Fracture Manipulation

Neel Badhe[1], Christopher Deacon[2,*], Benjamin J Ollivere[2]

[1]School of Clinical Medicine, University of Cambridge, CB2 3BU Cambridge, UK
[2]Injury, Recovery and Inflammation Sciences, School of Medicine, University of Nottingham, NG7 2UH Nottingham, UK
*Correspondence: christopher.deacon@nottingham.ac.uk (Christopher Deacon)

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Abstract

Distal radius fractures (DRFs) are one of the most common orthopaedic injuries seen in the Accident and Emergency (A&E) Department, accounting for 17% of all fractures. They are associated with significant morbidity, with substantial economic and societal costs due to the high incidence of these injuries. Initial management of displaced fractures consists of prompt reduction of the fracture in A&E and application of a moulded plaster cast to hold the fracture. However, there is currently no consensus on the best anaesthetic to use during the manipulation procedure. The most frequently used are local anaesthetic techniques, namely haematoma block and Bier's block. Current UK guidelines recommend the use of intravenous local anaesthetic (Bier's block) for manipulation. However, surveys of national practice show significant variations in practice, with haematoma block being the most commonly used technique. This article summarises the current evidence regarding the anaesthetic techniques for performing wrist manipulations.

Keywords: intravenous regional anaesthesia; haematoma block; radius fractures; analgesia

1. Introduction

Distal radius fractures (DRFs) are one of the most common orthopaedic injuries seen in the Accident and Emergency (A&E) Department, accounting for 17.5% of all fractures [1]. The annual incidence of DRFs is 16.2 per 10,000 [2], with an estimated lifetime risk of 15% for females and 2% for males [3]. DRFs are bimodally distributed between young patients with high-energy fractures and older patients with low-energy, osteoporotic fractures [4]. Due to the increased prevalence of osteoporosis and reduced bone density in post-menopausal women, DRFs occur more frequently in older, female patients, with a peak incidence in women aged over 65 [5]. As the global population ages and risk factors such as osteoporosis become more prevalent, the global incidence of DRFs is expected to increase. This trend has been observed in a large registry study, which found that the annual number of DRFs increased by 31% over the last two decades [6].

DRFs are associated with significant morbidity and cause a substantial economic and societal burden. In the elderly, distal radius fractures are associated with functional decline, reduced quality of life, and increased healthcare costs [7]. In working adults, distal radius fractures are associated with significant absenteeism, with an average of 9.2 work weeks lost [8]. Treatment costs have also increased, largely driven by the growing use of open reduction and internal fixation (ORIF) for these injuries [9]. Despite the high frequency of these fractures, the optimal management of these injuries remains controversial.

Displaced fractures are typically reduced and stabilised with a moulded plaster cast. Given the painful nature of this procedure, various anaesthetic agents have been used to reduce the pain of manipulation. Options include intravenous regional anaesthesia, haematoma block with adjunctive inhaled anaesthesia, general anaesthetic, and regional nerve blocks [10].

The British Orthopaedic Association (BOA) and the National Institute for Health and Care Excellence (NICE) recommend intravenous local anaesthetic (Bier's block) for DRF manipulation [11,12]. Despite this, surveys of national practice in the UK show significant variations in practice, with haematoma block being the most frequently used anaesthetic technique (50–62%) [13]. This highlights a marked divergence from national guidance and lack of clinical consensus. This article aims to summarise the current evidence for anaesthetic techniques used in distal radius fracture manipulation and identify further areas for research.

Therefore, a review of the literature was conducted on 9 July 2025 to identify all peer-reviewed studies investigating the efficacy and safety of analgesic and anaesthetic agents for distal radius fracture manipulation using the search strategy: "distal radius fracture" AND ("manipulation" OR "reduction" OR "management") AND ("analgesia" OR "anaesthesia" OR "anesthesia" OR "haematoma block" OR "hematoma block" OR "Bier's block" OR "intravenous regional anaesthesia" OR "regional block" OR "nerve block" OR "general anaesthesia" OR "inhaled anaesthetic" OR "Entonox" OR "Penthrox").

Searches of OVID EMBASE (https://www.wolterskluwer.com/en/solutions/ovid/embase-903) [14], OVID Medline (https://www.wolterskluwer.com/en/solutions/ovid/ovid-medline-901) [15] and Cochrane CENTRAL (https://www.cochranelibrary.com/central) [16] databases were

Table 1. Step-by-step procedure for the two most commonly performed distal radius fracture (DRF) manipulation techniques.

Bier's block	Haematoma block
1. A double-cuffed pneumatic tourniquet is inflated around the upper arm to 100 mmHg above systolic blood pressure[1]	1. The overlying skin is first prepared with an antiseptic solution such as chlorhexidine or povidone-iodine
2. Following inflation of the tourniquet, local anaesthetic is given via a small-bore cannula. Injection typically occurs in the dorsum of the hand, distal to the fracture site	2. The fracture step is then palpated by the performing clinician
3. If venous access distal to the fracture cannot be obtained, venous access proximally in the antecubital fossa may be used[2]	3. A needle is passed percutaneously into the fracture site from the dorsal surface of the forearm
4. The tourniquet cuff must be kept inflated for a minimum of 30 minutes before deflating, with a clinician present throughout the procedure	4. The attached syringe is aspirated to assess for presence of fracture haematoma
	5. Once positioning of the needle within the fracture has been confirmed, the local anaesthetic is injected into the fracture site

[1] This ensures the anaesthetic effect remains localised to the injured limb and prevents local anaesthetic systemic toxicity (LAST), which can cause several complications such as arrhythmia, seizure, neurological toxicity, with loss of consciousness, coma, respiratory arrest and death [17].

[2] A randomised trial of 100 patients comparing the dorsum of the hand and the antecubital fossa to determine the best location for local anaesthetic injection found no significant difference in anaesthesia between the two groups [18]. However, this study reported more problems associated with venous access and plaster application in the dorsal hand group.

performed. In addition, screening of the grey literature was completed using Google Scholar and a bibliographic assessment of relevant previous review articles. Randomised controlled trials, case reports and series, retrospective and prospective studies, and systematic reviews were included. Animal studies, review articles, and conference abstracts were excluded. Studies not published in the English language were identified through the screening process and subsequently excluded.

2. Anaesthetic Techniques for DRF Manipulation

2.1 Intravenous Regional Anaesthesia (IVRA)

Intravenous regional anaesthesia (IVRA), or Bier's block, involves the administration of intravenous local anaesthetic into the injured limb to provide anaesthesia to the whole upper limb. A step-by-step procedure on how to perform a Bier's block is presented in Table 1 (Ref. [17,18]). There are several contraindications to Bier's block, which have been summarised in Table 2 (Ref. [19]).

Historically, concerns have been raised regarding the safety of Bier's block, given that local anaesthetics may cause neurological and cardiac toxicity when given intravenously or at high doses [17,20]. While bupivacaine is no longer recommended due to the risk of serious cardiac adverse events, prilocaine has greater pulmonary uptake than bupivacaine (40% vs 12%) and consequently lower systemic plasma concentrations [21]. Intravenous prilocaine at a dose of 3 mg/kg in the context of Bier's block has been shown to be safe in a retrospective UK cohort of 45,000 patients [22], with no convulsions, arrhythmia, or fatalities recorded.

2.2 Haematoma Block

Haematoma block involves the administration of local anaesthetic directly to the fracture site. A step-by-step procedure on how to perform a haematoma block is presented in Table 1. There are several different options available for the local anaesthetic, such as lidocaine (short-acting), bupivacaine, and levobupivacaine (long-acting) [23]. These can be used either alone or in combination to provide longer-lasting anaesthesia as required. History of allergy or anaphylaxis to local anaesthetic is a contraindication to haematoma block (Table 3, Ref. [24]).

2.3 Bier's Block vs Haematoma Block

Uncertainty remains regarding the optimal method of anaesthesia for performing wrist manipulations. Three randomised trials [25–27], one pseudo-randomised study [28] and one non-randomised prospective cohort study [29] comparing various anaesthetic modalities have been published. However, all these studies had serious methodological limitations; they had small sample sizes and did not assess long-term, clinically important outcomes. Additionally, most did not measure long-term patient-reported outcome measures (PROMs) or conduct economic analyses. A Cochrane systematic review on the subject in 2002 concluded: "there is insufficient robust evidence from randomised trials to establish the relative effectiveness of different methods of analgesia", underlining the need for further research in this field [10].

However, there is evidence to suggest haematoma block provides inferior pain relief to Bier's block despite this being the most used anaesthetic technique [27]. In Kendall's randomized controlled trial (RCT), patients experienced reduced pain when receiving a Bier's block compared to receiving a haematoma block (median visual ana-

Table 2. Absolute and relative contraindications to Bier's block [19].

Absolute contraindications	Relative contraindications
Patient refusal	Diagnosis of sickle cell disease
History of allergy or anaphylaxis to local anaesthetic	Diagnosis of Raynaud's disease
Crush injury/compromised circulation of the affected limb	Diagnosis of scleroderma
Deep vein thrombosis or thrombophlebitis of the limb	Obesity impacting venous access and tourniquet application due to large extremities
Uncontrolled hypertension with a systolic blood pressure greater than 200 mmHg	Coagulopathies
Open wounds or significant injuries to the limb	Arrhythmias
Concomitant ipsilateral humerus fracture preventing tourniquet placement	Neuropathies
Infection or severe trauma at the injection site	Paget's disease

Table 3. Absolute and relative contraindications to haematoma block [24].

Absolute contraindications	Relative contraindications
Allergies to local anaesthetics	Bleeding disorders
Open fracture	Anticoagulation use
Overlying cellulitis	
Neurovascular deficit	
Uncooperative patient	

log scale (VAS) pain score 2.8 vs 5.2; $p < 0.001$). Patients in the Bier's block group also found the fracture manipulation to be less painful compared to the haematoma block group (median VAS pain score 1.5 vs 3.0; $p < 0.01$). Additionally, an observational study of 200 DRFs found that patients undergoing Bier's block for manipulation were significantly more likely to have the fracture successfully reduced and normal anatomy restored compared to the haematoma block ($p < 0.005$) [30]. This finding has also been demonstrated in several other studies [23,25], in addition to Kendall's RCT ($p = 0.003$) and Handoll's Cochrane review. No further randomised trials have been published in the last 20 years and to date no trial has been published comparing the cost-effectiveness of these treatments.

The reasons why Bier's block is not commonly used are multifactorial. Bier's block is resource-intensive and has previously been associated with significant risks such as local anaesthetic systemic toxicity [17]. Therefore, patients require close monitoring during and after the procedure. It may be slower to perform than a haematoma block [26] and necessitates the presence of medical staff throughout the procedure to administer the block safely. A&E departments are under increasing pressure to meet clinical targets and ensure waiting times remain short and therefore may not have the resources and capacity to allow staff to spend the time required to perform Bier's block.

2.4 General Anaesthetic

General anaesthetic (GA) has previously been employed with good effect for the manipulation of wrist fractures. However, owing to the logistical challenges in ensuring the patient has been appropriately starved and the necessity of an airway-trained anaesthetist, the use of GA for wrist manipulations has declined from approximately 32% in 1997 [31] to 2% in 2013 [32], likely due to alternatives being more cost- and time-effective.

A prospective study of 58 DRFs comparing the use of haematoma block with general anaesthetic found that patients given a haematoma block experienced greater pain during manipulation ($p < 0.01$), but patients in the GA group experienced more post-manipulation pain ($p < 0.01$) [29]. Radiological outcomes did not differ significantly between the two groups. Notably, this study found that haematoma block was more efficient with regard to time and the resources required, which is becoming increasingly important due to the aging population and rising demands on healthcare systems. Consequently, general anaesthesia is rarely used for the manipulation of DRFs in the emergency department.

2.5 Regional Nerve Blocks

Median, radial, and ulnar nerve or brachial plexus blocks are frequently used to provide anaesthesia to the upper limb. Ultrasound-guidance (USG) may be used to visualise nerve morphology in real-time and aid with the placement of the anaesthetic. Ultrasound-guided block of the radial nerve at the supracondylar level has been shown to be effective for the manipulation of wrist fractures [33]. Given the specialist skills required to perform nerve blocks, routine use of nerve blocks for initial manipulation of distal radius fractures is uncommon.

However, due to its potential to improve accuracy and minimise complications, there is growing interest in USG techniques for DRF manipulation [34]. A recent case series of 51 paediatric distal radius fracture manipulations reported successful anatomical manipulation with ultrasound in 95.3% of patients and low redisplacement rates (5.9%) [35]. However, a study comparing the effect of radial, ulnar and median nerve blocks with the haematoma block at reducing pain found that haematoma block more frequently allowed for a painless manipulation (68% vs 44%) [36]. Additionally, a systematic review of ultrasound-guided DRF manipulations in adult patients found that USG manipulation did not prevent malalignment over landmark-based manipulation [37].

2.6 Inhaled Anaesthetic Agents

Adjuvant nitrous oxide (Entonox) or methoxyflurane (Penthrox) may be used during distal radius fracture manipulations. The use of inhaled analgesics alone for wrist manipulation has been documented in the literature [38]. However, the analgesic effect offered by these agents alone may be inadequate and is not currently recommended in the British Society for Surgery of the Hand (BSSH) Blue Book guidelines [39].

2.6.1 Entonox

Entonox, often referred to as “gas and air”, is a mixture of 50% oxygen and 50% nitrous oxide that can be used to provide analgesia in spontaneously breathing patients for short procedures. Entonox has a rapid onset and offset, with analgesia starting from 20 seconds after inhalation with a peak effect after 3 to 5 minutes [40]. This makes it an attractive option for several procedures and there is growing interest in the use of Entonox for the manipulation of DRFs.

As nitrous oxide diffuses into air-filled body cavities, the volume or pressure of these cavities will increase. Therefore, administration of nitrous oxide is contraindicated in patients with a head injury or elevated intracranial pressure [41]. Other contraindications include haemodynamic instability, drug intoxication, pneumothorax, bowel obstruction or any condition associated with a pathological air-filled cavity. Entonox should be used with caution in patients with chronic obstructive pulmonary disease (COPD) or congestive cardiac failure as studies have shown that nitrous oxide may cause slight cardiac depression [40].

Licensed for use in both adults and children, Entonox has seen widespread use in the UK, Australia, and several countries across Europe [42]. However, Entonox lacks Food and Drug Administration (FDA) approval for use in the United States [43].

A retrospective study investigating the use of Entonox, in combination with intranasal diamorphine, for the manipulation of 100 paediatric DRFs reported a successful reduction in 90% of fractures, with only 3% of patients requiring manipulation and K-wire or internal fixation [44]. It should be noted that NICE guidelines state that gas and air (nitrous oxide and oxygen) should not be used on their own when reducing dorsally displaced DRFs in the emergency department [12]. Therefore, Entonox may be primarily useful as an adjunctive therapy in the manipulation of distal radius fractures.

A number of studies comparing Entonox with traditional anaesthetic techniques for DRF manipulation have been conducted [45,46]. A randomised trial of 67 patients comparing Entonox (n = 35) with Bier’s block (n = 32) found that the use of Bier’s block was associated with reduced VAS pain scores (2.2 vs 5.8, $p < 0.0001$), but that manipulations using Entonox were significantly shorter (11.1 vs 25.6 minutes, $p < 0.0001$) [45]. No significant difference between the complication rate ($p = 0.115$) or failed manipulation rate ($p = 0.086$) of the two groups. A prospective study of 67 patients comparing the efficacy of Entonox (n = 33) with haematoma block (n = 34) was also conducted [46]. This study reported that patients given haematoma block reported reduced VAS pain scores during the reduction (2.80 vs 7.19, $p < 0.0001$) and a superior relative change in VAS pain scores compared to before the procedure (58% decrease in the haematoma block group compared to 3% increase in the Entonox group, $p < 0.0001$). These studies support NICE guidelines, indicating that Entonox alone may provide insufficient analgesia for DRF manipulation in the emergency department.

2.6.2 Penthrox

Penthrox (methoxyflurane) is a halogenated hydrocarbon inhaled anaesthetic that has seen rising interest over recent years. Like Entonox, Penthrox may be a valuable adjunct to traditional anaesthetic techniques. Penthrox has also demonstrated significant efficacy and safety for use on its own, however this has not been investigated in randomised trials.

Penthrox has several advantages over traditional anaesthetic techniques, such as its ease of use, rapid effectiveness, and the reduced requirement for monitoring and staff [47]. Use of methoxyflurane has been shown to accurately estimate the level of pain so to determine anaesthetic required to minimise adverse effects [38].

A retrospective review of 54 fracture manipulations, including several distal radius fractures, reported a 100% success rate in achieving adequate and safe reduction using Penthrox to provide analgesia [48]. Additionally, an observational study of 145 patients comparing the efficacy of methoxyflurane with propofol (general anaesthetic) in the reduction of DRFs found that patients receiving methoxyflurane reported no pain during manipulation more than two times compared to patients that received propofol [38].

Additionally, while there have been concerns about the safety of using Penthrox in elderly and comorbid populations, a recent safety study found that Penthrox administration was not associated with an increased risk of hepatotoxicity but was associated with a reduced risk of nephrotoxicity compared with other routinely administered analgesics [49]. Additionally, a subgroup analysis of an RCT found that Penthrox provided similar pain relief and safety compared to intravenous (IV) standard in elderly patients with moderate to severe trauma pain [50].

Penthrox also has a number of contraindications including hypersensitivity to methoxyflurane or any fluorinated or inhaled anaesthetic, malignant hyperthermia, acute intoxication with drugs or alcohol, altered consciousness, hepatic or renal impairment, cardiovascular instability, and respiratory depression [51].

However, its regulatory status varies globally. Penthrox has been licensed for use in adults in the UK and Europe since 2015 [49] and has been licensed and used safely in children in Australia since the 1970s [52]. However, the FDA withdrew Penthrox from the US market in 2005 due to reports of nephrotoxicity and hepatotoxicity, but it is currently undergoing clinical trials for reintroduction as an analgesic [49].

Studies have shown that Entonox and Penthrox are safe and provide superior analgesia to placebo. However, there is little evidence to indicate that Penthrox has superior clinical efficacy or cost-effectiveness compared to Entonox [53,54]. However, a recent study comparing these inhaled anaesthetics in prehospital trauma settings found that Penthrox provided faster pain relief than Entonox, but at an additional cost of 12.30 GBP per patient (1 GBP = 1.35 USD) [55]. Penthrox also has several advantages, such as ease of administration and portability. It has therefore been proposed that Penthrox has significant potential for use in emergency situations in difficult-to-reach locations and in mass-casualty situations [54].

3. Limitations

This review has several limitations. The review was narrative in nature and therefore did not follow a formal systematic methodology (e.g., Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines). Only English-language, peer-reviewed articles were included in the review, potentially introducing selection bias. Of the included studies, many were outdated, had small sample sizes, and were methodologically limited (often non-randomised with poor outcome reporting), highlighting the need for further large-scale RCTs. No formal quality or risk of bias assessment was conducted. Evidence on the safety, efficacy, and cost of inhaled anaesthetic agents was limited, particularly in elderly or comorbid populations. Additionally, the absence of formal cost-effectiveness analyses limits the ability to draw definitive conclusions and effectively inform evidence-based national guidelines.

4. Conclusion

There is currently no consensus among orthopaedic surgeons as to which anaesthetic technique is best for the manipulation of these fractures in a plaster cast. Current British Orthopaedic Association Standards for Trauma (BOAST) and NICE guidelines recommend the use of intravenous local anaesthetic (Bier's block) for manipulation. Despite this, surveys show the haematoma block being the most commonly used technique.

Based on the current evidence, Bier's block should be considered the first-line analgesic technique for distal radius fracture manipulation due to its superior pain control and reduction outcomes. Inhaled anaesthetics such as Entonox and Penthrox show promise as adjuncts to traditional techniques, with Penthrox also demonstrating potential as an effective stand-alone option. However, their routine use is limited by a lack of RCT evidence, and further trials are needed to establish their comparative efficacy and safety.

Future studies should also consider patient age, fracture complexity, and the need for secondary surgical intervention, while also including cost-effective analyses. Results from such trials could directly inform national guidelines, supporting evidence-based clinical decision-making and optimal resource allocation.

Key Points

• Distal radius fractures are one of the most common orthopaedic injuries, associated with significant morbidity and substantial economic and societal costs.

• Initial management of displaced fractures typically consists of prompt reduction of the fracture in A&E and application of a moulded plaster cast to hold the fracture.

• Surveys show haematoma block is the most commonly used technique in the UK, despite BOAST guidelines recommending the use of intravenous local anaesthetic (Bier's block) for manipulation.

• Inhaled anaesthetics show promise as adjuncts (Entonox or Penthrox) or alone (Penthrox).

Availability of Data and Materials

Not applicable.

Author Contributions

NB: Conceptualisation and Study Design, Methodology, Writing Original Draft. CD: Methodology, Writing Original Draft, Conceptualisation and Study Design. BJO: Conceptualisation and Study Design Supervision. All authors contributed to revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. Injury. 2006; 37: 691–697. https://doi.org/10.1016/j.injury.2006.04.130.

[2] Karl JW, Olson PR, Rosenwasser MP. The Epidemiology of Upper Extremity Fractures in the United States, 2009. Journal of Orthopaedic Trauma. 2015; 29: e242–e244. https://doi.org/10.1097/BOT.0000000000000312.

[3] Cummings SR, Kelsey JL, Nevitt MC, O'DOWD KJ. EPIDEMIOLOGY OF OSTEOPOROSIS AND OSTEOPOROTIC FRACTURES. Epidemiologic Reviews. 1985; 7: 178–208. https://doi.org/10.1093/oxfordjournals.epirev.a036281.

[4] Rundgren J, Bojan A, Mellstrand Navarro C, Enocson A. Epidemiology, classification, treatment and mortality of distal radius fractures in adults: an observational study of 23,394 fractures from the national Swedish fracture register. BMC Musculoskeletal Disorders. 2020; 21: 88. https://doi.org/10.1186/s12891-020-3097-8.

[5] Luo Z, Zhu W, Jiang C, He W, Zuo H. Characteristics of distal radius fractures in east China-an observational cohort study of 1954 individual fractures. BMC Musculoskeletal Disorders. 2023; 24: 627. https://doi.org/10.1186/s12891-023-06742-x.

[6] Viberg B, Tofte S, Rønnegaard AB, Jensen SS, Karimi D, Gundtoft PH. Changes in the incidence and treatment of distal radius fractures in adults - a 22-year nationwide register study of 276,145 fractures. Injury. 2023; 54: 110802. https://doi.org/10.1016/j.injury.2023.05.033.

[7] Babatunde OO, Bucknall M, Burton C, Forsyth JJ, Corp N, Gwilym S, *et al*. Long-term clinical and socio-economic outcomes following wrist fracture: a systematic review and meta-analysis. Osteoporosis International. 2022; 33: 753–782. https://doi.org/10.1007/s00198-021-06214-9.

[8] MacDermid JC, Roth JH, McMurtry R. Predictors of time lost from work following a distal radius fracture. Journal of Occupational Rehabilitation. 2007; 17: 47–62. https://doi.org/10.1007/s10926-007-9069-0.

[9] Nandyala SV, Giladi AM, Parker AM, Rozental TD. Comparison of Direct Perioperative Costs in Treatment of Unstable Distal Radial Fractures: Open Reduction and Internal Fixation Versus Closed Reduction and Percutaneous Pinning. The Journal of Bone and Joint Surgery. American Volume. 2018; 100: 786–792. https://doi.org/10.2106/JBJS.17.00688.

[10] Handoll HH, Madhok R, Dodds C. Anaesthesia for treating distal radial fracture in adults. The Cochrane Database of Systematic Reviews. 2002; 2002: CD003320. https://doi.org/10.1002/14651858.CD003320.

[11] British Orthopaedic Association. The Management of Distal Radial Fractures. 2017. Available at: https://www.boa.ac.uk/static/eca9b368-6c1d-4a44-b98de7cfc9247273/5c46835b-7d0f-40c4-89112dd5beddcda7/boast%20-%20the%20management%20of%20distal%20radial%20fractures.pdf (Accessed: 1 March 2025).

[12] National Institute for Health and Care Excellence (NICE). Surveillance report (exceptional review) 2018 - Fractures (non-complex): assessment and management (2016) NICE guideline NG38. National Institute for Health and Care Excellence: London. 2018.

[13] Oakley B, Busby C, Kulkarni S, Arnold SJ, Kulkarni SS, Ollivere BJ. Manipulation of distal radius fractures: a comparison of Bier's block vs haematoma block. The Annals of the Royal College of Surgeons of England. 2023; 105: 434–440. https://doi.org/10.1308/rcsann.2022.0116.

[14] OVID. EMBASE. 2025. Available at: https://www.wolterskluwer.com/en/solutions/ovid/embase-903 (Accessed: 9 July 2025).

[15] OVID. Ovid MEDLINE. 2025. Available at: https://www.wolterskluwer.com/en/solutions/ovid/ovid-medline-901 (Accessed: 9 July 2025).

[16] Cochrane. Cochrane Central Register of Controlled Trials (CENTRAL). 2025. Available at: https://www.cochranelibrary.com/central/about-central (Accessed: 9 July 2025).

[17] El-Boghdadly K, Pawa A, Chin KJ. Local anesthetic systemic toxicity: current perspectives. Local and Regional Anesthesia. 2018; 11: 35–44. https://doi.org/10.2147/LRA.S154512.

[18] Blyth MJ, Kinninmonth AW, Asante DK. Bier's block: a change of injection site. The Journal of Trauma. 1995; 39: 726–728. https://doi.org/10.1097/00005373-199510000-00021.

[19] Kraus GP, Rondeau B, Fitzgerald BM. Bier Block. StatPearls. StatPearls Publishing: Treasure Island (FL). 2024.

[20] Long B, Chavez S, Gottlieb M, Montrief T, Brady WJ. Local anesthetic systemic toxicity: A narrative review for emergency clinicians. The American Journal of Emergency Medicine. 2022; 59: 42–48. https://doi.org/10.1016/j.ajem.2022.06.017.

[21] Boer F. Drug handling by the lungs. British Journal of Anaesthesia. 2003; 91: 50–60. https://doi.org/10.1093/bja/aeg117.

[22] Bartholomew K, Sloan JP. Prilocaine for Bier's block: how safe is safe? Archives of Emergency Medicine. 1990; 7: 189–195. https://doi.org/10.1136/emj.7.3.189.

[23] Maleitzke T, Plachel F, Fleckenstein FN, Wichlas F, Tsitsilonis S. Haematoma block: a safe method for pre-surgical reduction of distal radius fractures. Journal of Orthopaedic Surgery and Research. 2020; 15: 351. https://doi.org/10.1186/s13018-020-01819-y.

[24] Yang T. Hematoma Blocks. 2023. Available at: https://kwaktalk.org/ortho/2023/1/29/hematoma-blocks (Accessed: 1 March 2025).

[25] Abbaszadegan H, Jonsson U. Regional anesthesia preferable for Colles' fracture. Controlled comparison with local anesthesia. Acta Orthopaedica Scandinavica. 1990; 61: 348–349. https://doi.org/10.3109/17453679008993533.

[26] Cobb AG, Houghton GR. Local anaesthetic infiltration versus Bier's block for Colles' fractures. British Medical Journal (Clinical Research Ed.). 1985; 291: 1683–1684. https://doi.org/10.1136/bmj.291.6510.1683-a.

[27] Kendall JM, Allen P, Younge P, Meek SM, McCabe SE. Haematoma block or Bier's block for Colles' fracture reduction in the accident and emergency department–which is best? Journal of Accident & Emergency Medicine. 1997; 14: 352–356. https://doi.org/10.1136/emj.14.6.352.

[28] Wardrope J, Flowers M, Wilson DH. Comparison of local anaesthetic techniques in the reduction of Colles' fracture. Archives of Emergency Medicine. 1985; 2: 67–72. https://doi.org/10.1136/emj.2.2.67.

[29] Funk L. A prospective trial to compare three anaesthetic techniques used for the reduction of fractures of the distal radius. Injury. 1997; 28: 209–212. https://doi.org/10.1016/s0020-1383(96)00183-0.

[30] Oakley B, Busby C, Kulkarni S, Arnold SJ, Kulkarni SS, Ollivere BJ. Manipulation of distal radius fractures: a comparison of Bier's block vs haematoma block. Annals of the Royal College of Surgeons of England. 2023; 105: 434–440. https://doi.org/10.1308/rcsann.2022.0116.

[31] Graham CA, Gibson AJ, Goutcher CM, Scollon D. Anaesthesia for the management of distal radius fractures in adults in Scottish hospitals. European Journal of Emergency Medicine. 1997; 4: 210–212. https://doi.org/10.1097/00063110-199712000-00006.

[32] Sprot H, Metcalfe A, Odutola A, Palan J, White S. Management of distal radius fractures in emergency departments in England

and Wales. Emergency Medicine Journal. 2013; 30: 211–213. https://doi.org/10.1136/emermed-2011-200782.
[33] Aydin AA, Bilge S, Kaya M, Aydin G, Cinar O. Novel technique in ED: supracondylar ultrasound-guided nerve block for reduction of distal radius fractures. The American Journal of Emergency Medicine. 2016; 34: 912–913. https://doi.org/10.1016/j.ajem.2016.02.032.
[34] Ottenhoff J, Kongkatong M, Hewitt M, Phillips J, Thom C. A Narrative Review of the Uses of Ultrasound in the Evaluation, Analgesia, and Treatment of Distal Forearm Fractures. The Journal of Emergency Medicine. 2022; 63: 755–765. https://doi.org/10.1016/j.jemermed.2022.09.012.
[35] Wu X, Meng X, Wang S, Shen X. Ultrasound-guided closed reduction of distal radius Salter-Harris I and II fracture in children. European Journal of Trauma and Emergency Surgery. 2025; 51: 220. https://doi.org/10.1007/s00068-025-02889-5.
[36] Haasio J. Cubital nerve block vs haematoma block for the manipulation of Colles' fracture. Annales Chirurgiae et Gynaecologiae. 1990; 79: 168–171.
[37] Nema SK, Austine J, Ramasubramani P, Agrawal R. Ultrasound-Guided Manipulation does not Prevent Malalignment Over Landmark-Based Fracture Reduction in Distal Radius Fracture (Colles). Journal of Emergencies, Trauma, and Shock. 2023; 16: 35–42. https://doi.org/10.4103/jets.jets_157_22.
[38] Albavera-Gutierrez RR, Paredes-Herrera FJ, Gasca-López GA, Waldo-Castañón Z, Espinosa-Ramos MA, Valencia-Ledezma OE, *et al*. Implementation of Inhaled Methoxyflurane for the Reduction of Distal Radius Fractures in a Third-Level Hospital: A Descriptive Cohort Study. Emergency Care and Medicine. 2024; 1: 145–152. https://doi.org/10.3390/ecm1020016.
[39] BSSH. Management of Distal Radius Fractures. 2018. Available at: https://www.bssh.ac.uk/professionals/management_of_distal_radial_fractures.aspx (Accessed: 1 March 2025).
[40] Young A, Ismail M, Papatsoris AG, Barua JM, Calleary JG, Masood J. Entonox® inhalation to reduce pain in common diagnostic and therapeutic outpatient urological procedures: a review of the evidence. Annals of the Royal College of Surgeons of England. 2012; 94: 8–11. https://doi.org/10.1308/003588412X13171221499702.
[41] Hancock SM, Eastwood JR, Mahajan RP. Effects of inhaled nitrous oxide 50% on estimated cerebral perfusion pressure and zero flow pressure in healthy volunteers. Anaesthesia. 2005; 60: 129–132. https://doi.org/10.1111/j.1365-2044.2004.04035.x.
[42] WHO. Pre-review report: Nitrous oxide. 2023. Available at: https://cdn.who.int/media/docs/default-source/46th-ecdd/nitrous-oxide_46th-ecdd_critical-review_public-version.pdf (Accessed: 1 March 2025).
[43] Collins MR, Starr SA, Bishop JT, Baysinger CL. Nitrous oxide for labor analgesia: expanding analgesic options for women in the United States. Reviews in Obstetrics & Gynecology. 2012; 5: e126–e131.
[44] Kurien T, Price KR, Pearson RG, Dieppe C, Hunter JB. Manipulation and reduction of paediatric fractures of the distal radius and forearm using intranasal diamorphine and 50% oxygen and nitrous oxide in the emergency department: a 2.5-year study. The Bone & Joint Journal. 2016; 98-B: 131–136. https://doi.org/10.1302/0301-620X.98B1.36118.
[45] Goh PL, Lee SW, Goh SH. Analgesia for Adult Distal Radius Fracture Manipulation in the Emergency Department: Demand Valve Nitrous Oxide Compared with Intravenous Regional Anaesthesia. Hong Kong Journal of Emergency Medicine. 2002; 9: 181–187. https://doi.org/10.1177/102490790200900401.
[46] Man KH, Fan KP, Chan TN, Yue YM, Sin FP, Lam KW. A Prospective Clinical Trial Comparing Self-Administered Nitrous Oxide and Haematoma Block for Analgesia in Reducing Fracture of the Distal Radius in an Emergency Department. Hong Kong Journal of Emergency Medicine. 2010; 17: 126–131. https://doi.org/10.1177/102490791001700204.
[47] Eager MM, Nolan GS, Tonks K, Ramjeeawon A, Taylor N. Inhaled methoxyflurane (Penthrox) for analgesia in trauma: a systematic review protocol. Systematic Reviews. 2021; 10: 47. https://doi.org/10.1186/s13643-021-01600-0.
[48] Gray Stephens C, Dias A, Skinner E, Brennan C, Middleton RG, Angel CK. Penthrox enables quicker management of fractures, dislocations and more: learning lessons from expedited care of trauma patients during the COVID-19 pandemic. Annals of the Royal College of Surgeons of England. 2023; 105: S22–S27. https://doi.org/10.1308/rcsann.2021.0340.
[49] Qizilbash N, Kataria H, Jarman H, Bloom B, Bradney M, Oh M, *et al*. Real world safety of methoxyflurane analgesia in the emergency setting: a comparative hybrid prospective-retrospective post-authorisation safety study. BMC Emergency Medicine. 2023; 23: 100. https://doi.org/10.1186/s12873-023-00862-2.
[50] Serra S, Voza A, Ruggiano G, Fabbri A, Bonafede E, Sblendido A, *et al*. Efficacy, Practicality, and Safety of Inhaled Methoxyflurane in Elderly Patients with Acute Trauma Pain: Subgroup Analysis of a Randomized, Controlled, Multicenter, Open-Label Trial (MEDITA). Journal of Pain Research. 2020; 13: 1777–1784. https://doi.org/10.2147/JPR.S255532.
[51] NHS Highland. Penthrox (methoxyflurane) (Guidelines). 2025. https://www.rightdecisions.scot.nhs.uk/tam-treatments-and-medicines-nhs-highland/emergency-guidelines/penthrox-methoxyflurane-guidelines/ (Accessed: 1 March 2025).
[52] Royal Cornwall Hospitals NHS Trust. The use of Penthrox in Children and Young people (aged 5 – 18 years) in the Emergency Department Clinical Guideline. 2024. Available at: https://doclibrary-rcht.cornwall.nhs.uk/DocumentsLibrary/RoyalCornwallHospitalsTrust/Clinical/EmergencyDepartment/TheUseOfPenthroxInChildrenAndYoungPeopleInTheEmergencyDepartment.pdf?utm (Accessed: 1 March 2025).
[53] Rahman SM, Quinn E. BET 1: Green or blue for you? Methoxyflurane (Penthrox) or nitrous oxide/oxygen 50% mixture (Entonox) for the management of acute pain in the ED. Emergency Medicine Journal: EMJ. 2019; 36: 506–508. https://doi.org/10.1136/emermed-2019-208777.1.
[54] Porter KM, Siddiqui MK, Sharma I, Dickerson S, Eberhardt A. Management of trauma pain in the emergency setting: low-dose methoxyflurane or nitrous oxide? A systematic review and indirect treatment comparison. Journal of Pain Research. 2018; 11: 11–21. https://doi.org/10.2147/JPR.S150600.
[55] Smith MD, Rowan E, Spaight R, Siriwardena AN. Evaluation of the effectiveness and costs of inhaled methoxyflurane versus usual analgesia for prehospital injury and trauma: non-randomised clinical study. BMC Emergency Medicine. 2022; 22: 122. https://doi.org/10.1186/s12873-022-00664-y.