Systematic Review

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Journal of Children's Orthopaedics
2024, Vol. 18(5) 502–509
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DOI: 10.1177/18632521241262973
journals.sagepub.com/home/cho

Initial management of pediatric Gustilo–Anderson type I upper limb open fractures: Are antibiotics enough?

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Abstract

Purpose: The British Orthopaedic Association Standards for Trauma-4 includes pediatric Gustilo–Anderson type I upper limb open fractures and recommends surgical debridement as the preferred method of treatment. The reported incidence of fracture-related infection is low in patients with this injury pattern and the evidence supporting debridement is therefore weak. The aim of this systematic review is to compare infection rates between non-operative management and operative debridement in children with Gustilo I upper limb fractures who did not require surgical fixation.
Methods: A systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Eligibility criteria included patients <18 years with Gustilo–Anderson type I upper limb fractures managed with either antibiotics alone or with operative debridement. Patients in whom the fracture was stabilized were excluded, and the Risk Of Bias In Non-randomized Studies—of Interventions tool was used to evaluate bias.
Results: Eleven, predominantly retrospective studies were identified, involving 537 patients with fractures including 466 forearm, 70 wrist, and one humerus. A non-operative management strategy was used in 293 patients with one superficial infection (0.3%). Operative debridement was used in 244 patients with one superficial infection (0.4%).
Conclusion: The optimal management of Gustilo–Anderson type I pediatric upper limb fractures is unclear. Based on the current evidence base, surgical debridement does not appear to reduce the rate of infection. The decision to manage these injuries aggressively should therefore be individualized to consider patient age, mechanism, and clinical extent of injury.
Level of evidence: level II.

Keywords: Pediatrics, orthopedics, open fracture, upper limb

Introduction

Open fractures communicate with the external environment[1] and are generally treated emergently to prevent wound contamination and infection.[2] Classification systems from the Orthopaedic Trauma Society (OTS), the Orthopaedic Trauma Association—Open Fracture (OTA-OFC), and the Ganga classification attempt to classify these injuries.[3–6]

Gustilo et al.[7] stratified these injuries into three distinct types, based on mechanism, location, soft tissue damage, fracture pattern, and degree of contamination. This classification remains in common use and is of value in predicting infection.[7,8]

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Date received: 14 May 2024; accepted: 31 May 2024

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Injuries with a wound <1 cm, with minimal contamination or soft tissue involvement are classified type I.[9–11] The rate of infection in pediatric patients with this injury pattern is lower than their adult counterparts[12,13] particularity in the upper limb, and a thicker, vascularized periosteum may be a contributory factor.[12,13]

The British Orthopaedic Association Standards for Trauma (BOAST-4) considers an evidence base that is predominately derived from lower limb injuries and extrapolates this to include the upper limb,[14–16] recommending operative debridement and intravenous (IV) antibiotics in all cases, irrespective of patient age and fracture site.[14–16] There is a paucity of evidence that considers open fracture management and the relevance of the BOAST-4 in the pediatric population. The aim of this study was to examine the available published evidence to compare infection rates of non-operative management with operative debridement within this population and therefore evaluate the relevance of BOAST-4 to children with upper limb open fractures.

Material and methods

A systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the study was prospectively registered on PROSPERO: International prospective register of systematic reviews (Registration Number: CRD42023465576).

The literature search was conducted separately by two authors (OO) and (SH) and included OVID Medline, EMBASE, Cochrane, OrthoSearch, and Web of Science. These databases were systematically searched from inception until 13 December 2023, not limited by language with search terms: (pediatric or child or adolescent or teen or youth or toddler or baby or neonate) AND (Gustilo–Anderson or Open fracture) AND (upper limb or shoulder or clavicle or humerus or elbow or olecranon or radius or ulna or wrist or forearm).

All potentially relevant studies were initially screened based on title and abstract. Randomized controlled trials (RCTs), retrospective and prospective cohort studies, and case–control studies involving patients <18 years with Gustilo–Anderson type I upper limb fractures, managed with antibiotics ± emergency room debridement, formal operative debridement, or both were eligible for inclusion. Patients who underwent internal fixation were excluded. Full-text articles were selected for further consideration and data extraction by OO and SH with any disagreements resolved by consensus and with YG.

The Risk Of Bias In Non-randomized Studies—of Interventions (ROBINS-I tool)[17] was used by OO to assess the methodological quality of individual studies in seven domains[17] and arbitrated as required by (YG). The information that was recorded included publication date, author, country of origin, level of evidence, gender, mean age and range, total number of grade I upper limb fractures and their location, and length of follow-up.

The primary outcome measure was defined as the rate of infection. This was assessed in patients managed with formal debridement (operative group) or with antibiotics alone ± emergency room debridement (non-operative group). Additional information included plastic surgery input, use of oral/intravenous (IV) antibiotics, time from injury to first dose of antibiotics, and the length of antibiotic course.

Results

The initial search identified 1633 studies, of which 1537 were excluded on the basis of title and abstract. Ninety-six studies were suitable for full-text review and 11 studies were included in the final review based on the eligibility criteria (Figure 1). Ten retrospective and one prospective cohort study provided a total population of 537 fractures located in the forearm (n = 466), wrist (n = 70), and humerus (n = 1) (Table 1).

The ROBINS-I tool[17] considered that all studies were either moderately or severely impaired with no studies considered to be methodologically sound. This was generally due to retrospective studies, often with missing patient data and outcomes (Figure 2).

The weighted mean age was 10 (range = 2–18) years, with a range of follow-up between 4 weeks and 13 years (Tables 1 and 2). One study did not report participant age[18] and sex distribution was limited to two studies[19,20] (Table 1).

Non-operative management in isolation was considered in five studies,[18,19,21–23] operative management in isolation in four studies,[10,11,20,24] and two studies considered patients managed either non-operatively or operatively.[25,26] All studies reported using a course of IV antibiotics, with a weighted mean duration of 44 h (range = 24–168), and seven studies implemented an additional course of oral antibiotics.[10,20–24,26] Only three studies reported the interval between injury and first antibiotic dose, with a weighted mean of 5 h 41 min (range = 4 h 52 min to 6 h 47 min).[18,19,22] Debridement in the emergency room combined with IV antibiotics was utilized in seven studies,[18,19,21–23,25,26] and none reported plastic surgical involvement (Table 2).

Infection was reported in one patient managed with formal operative debridement (n = 1/244, 0.4%)[10] and in one patient managed non-operatively (n = 1/293, 0.3%)[25] (Table 3). The infection in the non-operative group occurred in a 10-year-old patient who presented with a superficial wound infection 4 days after initially being treated and discharged with IV antibiotics and emergency

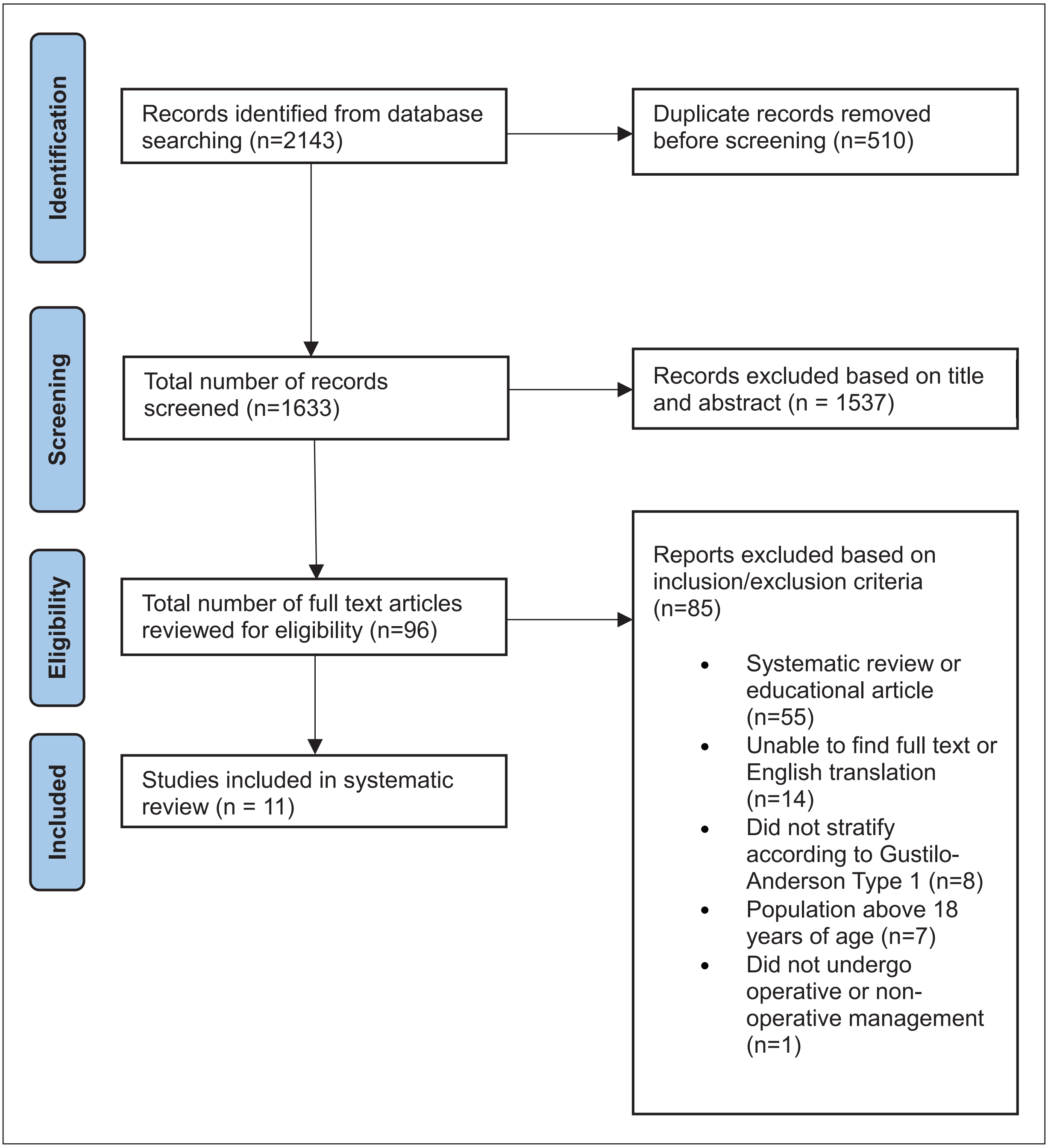

Figure 1. PRISMA flow chart illustrating the search strategy.

room wound irrigation.[25] He was subsequently managed with operative debridement and went on to achieve satisfactory fracture healing with an otherwise uneventful clinical course.[25]

In the operative debridement group, one superficial wound infection was noticed in a 12-year-old boy 6 weeks after initial operative debridement.[10] Notably, at the time of operative debridement, cultures grew *Staphylococcus epidermidis*, and this patient was initially treated with a 5-day course of parenteral antibiotics of, compared to the 3 days for other patients included in the study.[10] The superficial infection that developed 6 weeks later was treated with an further course of 4 days of intravenous and 10 days of oral antibiotics.[10]

Complications in the operative group (n = 30) included wrist stiffness (1),[25] loss of reduction (13),[10,20,24]

Table 1. Study characteristics.

Author	Year	Country	Study design	Mean age (range)	[a]Total number of patients with a Grade 1 upper limb fractures (location of fracture)	Total number of males with Grade 1 upper limb fractures	Total number of females with Grade 1 upper limb fracture
Godfrey, J., et al.	2019	The United States	Retrospective Cohort Study	10.1 (2 to 18 years old)	N = 199 (Wrist: 70, Forearm 129)	N/A	N/A
Goss, D, A., et al.	2017	The United States	Retrospective Cohort Study	8.8 (non-operative) and 11.2 (operative)	N = 126 (Forearm: 126)	N/A	N/A
Iobst, C. A., et al.	2014	The United States	Prospective Cohort Study	10 (4 to 17 years old)	N = 45 (Forearm: 45)	36	9
Doak, J., et al.	2009	The United States	Retrospective Case Series	Mean age not stated (2 to 15 years old)	N = 20 (Forearm: 20)	N/A	N/A
Lim, Y. J., et al.	2007	Singapore	Retrospective Case series	12 (3 to 14 years old)	N = 15 (Forearm: 15)	12	3
Iobst, C. A., et al.	2005	The United States	Retrospective Cohort Study	10 (4 to 15 years old)	N = 32 (Forearm: 32)	N/A	N/A
Luhmann, S. J., et al.	2004	The United States	Retrospective Cohort Study	10.3 (3.1 to 17.1 years old)	N = 23 (Forearm:23)	N/A	N/A
Greenbaum, B., et al.	2001	The United States	Retrospective Cohort Study	10.6 (2 to 16 years old)	N = 25 (Forearm 25)	N/A	N/A
Haasbeek, J., et al.	1995	Canada	Retrospective Cohort Study	9 (4 to 15 years old)	N = 22 (Humerus: 1, Forearm: 21)	N/A	N/A
Bazzi, A, A., et al	2014	The United States	Retrospective Cohort Study	8.6 (4-16 years old)	N = 27 (Forearm: 27)	N/A	N/A
Yang, E., et al	2003	The United States	Retrospective Cohort Study	N/A	N = 3 (Forearm: 3)	N/A	N/A

N/A = data not available (i.e. unable to stratify according to type 1 upper limb patients) or not applicable.
[a]Numbers exclude metalwork patients.

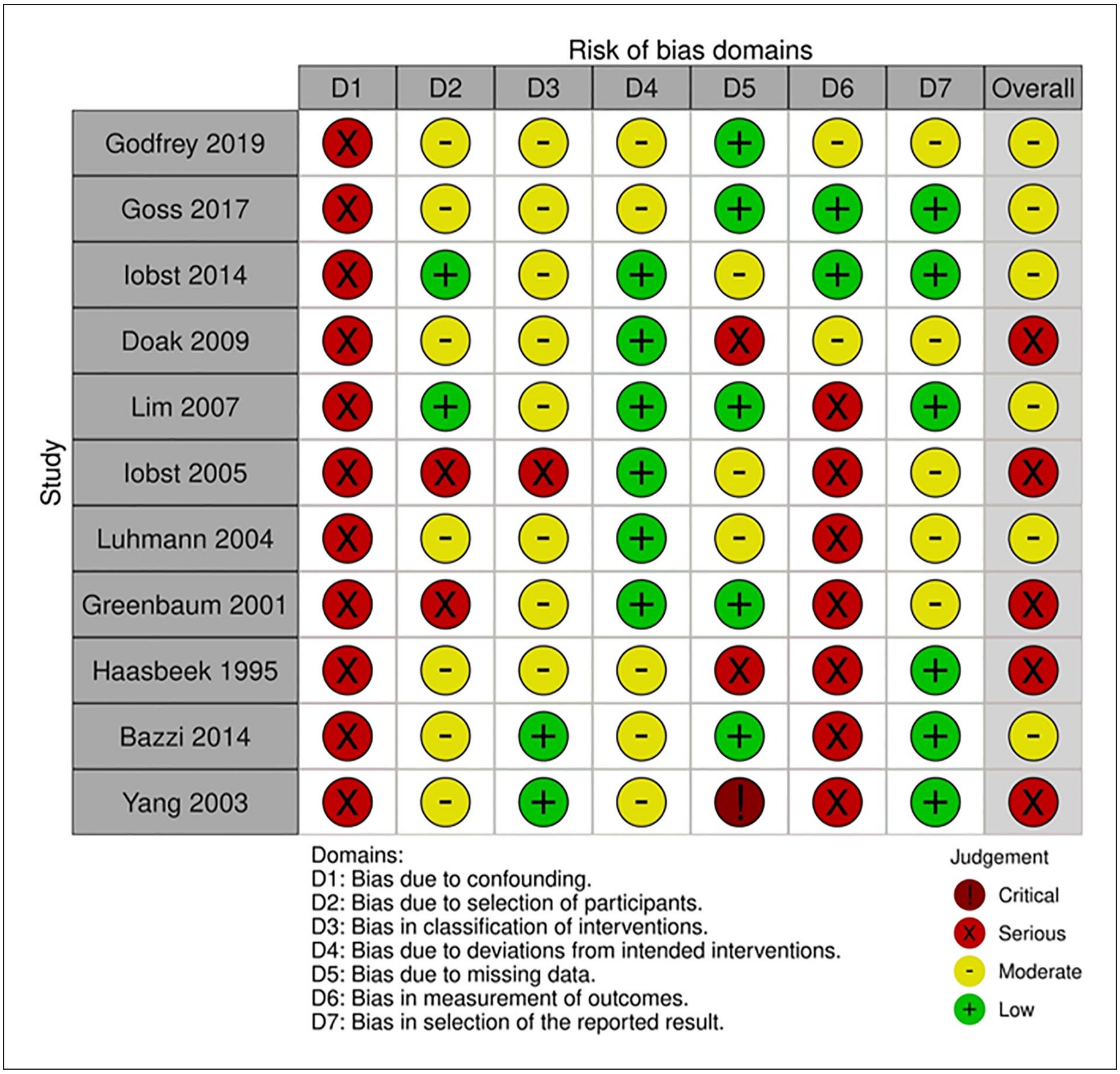

Figure 2. ROBINS-I risk of bias assessment.

refracture (3),[20,24,26] malunion (4),[24,25] delayed union (4),[24,25] temporary ulnar neuropathy (3),[10,25] anterior interosseous neuropraxia (1),[10] and combined superficial radial and median nerve injury (1).[10] Complications in the non-operative group (n=33) included loss of reduction (21),[19,25,26] refracture (10),[19,21,26] delayed union (1),[23] and a retained foreign body (1)[23] which was identified 4 weeks later and was removed in clinic with no evidence of a resultant infection.[23]

Discussion

BOAST guidelines recommend operative debridement and IV antibiotics in all open fractures irrespective of patient age and fracture site.[15,16] These guidelines are from an evidence base that is predominately derived from adult lower limb injuries, extrapolated to include the upper limb.[27,28]

To the authors' knowledge, this is the first systematic review that compared non-operative management with operative debridement in pediatric Gustilo–Anderson type I upper limb fractures. The review identified comparable rates of infection between operative debridement and non-operative groups with a very low overall rate. In addition, complication rates were similar in both groups and were rarely associated with the soft tissue component of the injury. Only one complication was a result of the intervention and involved a retained foreign body following non-operative fracture management.[23]

BOAST-4 guidelines may therefore be unnecessarily invasive, when blindly applied to a pediatric population with this injury pattern.[29] The poor quality of available evidence limits the ability to reach robust conclusions and challenge conventional wisdom, and it is therefore recommended that each case is considered on an individual basis with management

Table 2. Details of intervention.

Author (years)	Intervention (operative, non-operative, or both)	If operative, was there plastic surgery involvement (yes or no)	If non-operative, was there emergency room debridement (yes or no)	Intravenous or oral antibiotics or both	Mean time from fracture to first antibiotic dose (range)	Length of antibiotic (abx) course	Follow-up period (range)
Godfrey, J., et al. (2019)	Both	No	Yes	Intravenous	N/A	Operative group: mean 41.6 h (SD: 30.7) Non-operative group: Mean 10.9 h (SD: 19.7)	4 to 6 weeks
Goss, D, A., et al. (2017)	Both	No	Yes	Both	N/A	24 to 48 h + 5 to 7 days of oral abx	Minimum of 6 months
Iobst, C. A., et al. (2014)	Non-operative only	N/A	Yes	Intravenous	4 h 52 min (1 h 7 min to 10 h)	24 h	60 to 108 months
Doak, J., et al. (2009)	Non-operative only	N/A	Yes	Both	N/A	24 to 168 h	6 to 8 weeks
Lim, Y. J., et al. (2007)	Operative only	No	N/A	Both	N/A	1–4 days of IV abx + 1 week oral abx	3 to 48 months
Iobst, C. A., et al. (2005)	Non-operative only	N/A	Yes	Both	6 h 47 min	Range 48–72 h+ 1 week of oral abx in n = 4	8 weeks
Luhmann, S. J., et al. (2004)	Operative only	No	N/A	Both	N/A	Mean 7 days (range 2 to 17 days)	17 to 117 weeks
Greenbaum, B., et al. (2001)	Operative only	No	N/A	Both	N/A	IV abx 72 to 120 h. Length of oral abx not stated	2 to 29 months
Haasbeek, J., et al. (1995)	Operative only	No	N/A	Intravenous	N/A	N/A	3 to 13 years
Bazzi, A, A., et al. (2014)	Non-operative only	No	Yes	Both	N/A	One dose of IV abx + 3 to 14 days oral abx	4.2 ± 8 months
Yang, E., et al. (2003)	Non-operative only	No	Yes	Intravenous	Within 6 h	Up to 48 h	Mean = 5 months

N/A = data not available or not applicable.

Table 3. Rates of infection.

Author (years)	Total number of patients n = (operative vs non-operative)	Rates of infection (n, %)	
		Operative group	Non-operative group
Godfrey, J., et al. (2019)	N = 199 (152 vs 47)	0 (0%)	1 (2.1%)
Goss, D, A., et al. (2017)	N = 126 (7 vs 119)	0 (0%)	0 (0%)
Iobst, C. A., et al. (2014)	N = 45 (N/A vs 45)	N/A	0 (0%)
Doak, J., et al. (2009)	N = 20 (N/A vs 20)	N/A	0 (0%)
Lim, Y. J., et al. (2007)	N = 15 (15 vs N/A)	0 (0%)	N/A
Iobst, C. A., et al. (2005)	N = 32 (N/A vs 32)	N/A	0 (0%)
Luhmann, S. J., et al. (2004)	N = 23 (23 vs N/A)	0 (0%)	N/A
Greenbaum, B., et al. (2001)	N = 25 (25 vs N/A)	1 (4%)	N/A
Haasbeek, J., et al. (1995)	N = 22 (22 vs N/A)	0 (0%)	N/A
Bazzi, A, A., et al. (2014)	N = 27 (N/A vs 27)	N/A	0 (0%)
Yang, E., et al. (2003)	N = 3 (N/A vs 3)	N/A	0 (0%)
Total	**537 (244 vs 293)**	**1 (0.4%)**	**1 (0.3%)**

% of total number of fractures managed in that intervention arm. Data rounded to the nearest one decimal figure.
Fractures undergoing operative debridement only, that is, fractures with metalwork inserted excluded.
N/A = data not available.
Bold Significance was not calculated as part of the study analysis.

based on age, mechanism of injury, level of contamination, and any other relevant clinical considerations.

Conclusion

Based on the limited current evidence base, surgical debridement of Gustilo I upper limb fractures in a pediatric population has the same infection rates as not performing a surgical debridement and the BOAST-4 guidelines may be excessive for this specific subgroup. Treatment should be considered on an ad hoc basis, and a level 1 study is the recommended next step to identify the optimal treatment.

Acknowledgments

The authors thank the NHS librarian team at St George's Hospital. In particular, Ayo Ogundipe and Karen John-Pierre for their assistance in ensuring that a robust literature search was conducted.

Author contributions

O.O. (primary author) took the lead in the design, methodology (including the literature search), data extraction, and implementation of the research. He also drafted the manuscript and designed the tables and the figures. S.H. (secondary author) assisted O.O. in the drafting of the manuscript and the design of the tables and figures. She also performed the secondary literature search and separately corroborated the data extraction. A.B., C.H., F.M., and Y.G. conceived of the presented idea. A.B. also contributed to the design of the study. F.M. and Y.G. both also contributed in providing critical feedback which helped to shape the research, analysis, and the manuscript.

Declaration of conflicting interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The authors request that the following individuals not be approached to review our manuscript as they are listed as co-authors: Ms Y.G., BSc, MD, PhD, St George's University Hospitals NHS Foundation Trust, London, UK and Mr F.M., MBBChB, MSc, PhD, University Hospitals Bristol and Weston NHS Foundation Trust, Bristol, UK.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical approval

Ethical approval was not required for this study.

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Supplemental material

Supplemental material for this article is available online.

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