NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of intramedullary distraction for upper limb lengthening

People can be born with different length arms, or this can be caused by disease, injury, nerve damage at birth, or surgery to remove bone tumours. In this procedure, through an incision, the upper arm bone is cut and a metal lengthening device (distractor) is put inside the bone (intramedullary) across the cut. After the operation, the device is gradually lengthened while new bone forms across the cut, increasing the length of the bone. The device is lengthened using an electric or magnetic internal motor, operated through a connecting cable or remotely. This process of lengthening and healing takes several months. The device may be removed through surgery or left in place.

Contents

Abbreviations

Word or phrase	Abbreviation
Intramedullary	IM
Limb length discrepancy	LLD

Introduction

The National Institute for Health and Care Excellence (NICE) prepared this interventional procedure overview to help members of the interventional procedures advisory committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and professional opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in May 2021.

Procedure name

- intramedullary distraction for upper limb lengthening

Professional societies

- British Limb Reconstruction Society
- British Orthopaedic Association
- British Society for Children's Orthopaedic Surgery
- British Orthopaedic Oncology Society (BOOS).

Description of the procedure

Indications and current treatment

People may have different limb lengths caused by trauma or infection or, more rarely, hypoplasia or dysplasia (congenital conditions such as achondroplasia,

Ollier's disease, and brachial plexus palsy). The condition can be unilateral or bilateral. Unequal limb lengths can lead to disability and limit functional ability.

Lengthening of a short upper limb can be attempted using external fixation devices, which exert force along the long axis of bone to induce new bone formation (called distraction osteogenesis). Often, the external fixation is removed and the new bone is augmented either by internal plate fixation or a nail inside the bone. Potential problems with external fixation include infection of the pin tracts, pain, angulation deformity of the bone, and neighbouring joint stiffness. External fixation devices may also present some practical and aesthetic challenges compared with a fully internal system.

What the procedure involves

Intramedullary distraction systems are intramedullary devices that are similar to intramedullary nails used for managing fractures. Once inserted and fixed, they can be mechanically lengthened over time using different techniques, resulting in a controlled lengthening of the bone. The device can be inserted into the humerus from the top (antegrade), though this may cause damage to the shoulder muscles, or the lower end (retrograde).

Under general anaesthesia, a humeral osteotomy is performed avoiding damage to the periosteum and its blood supply. The adjustable nail-like intramedullary device is then implanted into the intramedullary canal, and the proximal and distal sections of the device are fixed to the appropriate section of the humerus with sterile locking screws. Once implanted and fixed, the length of the device can be adjusted to provide an appropriate amount of compression and allow bony alignment at the osteotomy site. The device exerts a force along the long axis of the bone, which stimulates new bone formation (distraction osteogenesis) in the gap, causing bone lengthening. Over a period of days, weeks or months, sequential distractions are used to produce the target limb length.

Different devices achieve distraction in different ways. For example, some work mechanically by releasing a preloaded spring or using a motor driven extension. Others are non-invasive and use an external electromagnetic device..

The intramedullary device remains implanted until bone consolidation is completed. When there is radiological evidence of adequate bone consolidation across the gap, full function and limb use (weight bearing) is permitted. The device can usually be removed using standard surgical techniques or may be left in place indefinitely.

Efficacy summary

Mean lengthening achieved

In a retrospective case series of 9 children who underwent humeral lengthening (in 13 limbs), the average lengthening achieved was 6.6 ± 2.3 cm (range 1 to 9) in the motorised intramedullary (IM) nail group (n=6 limbs) and 8.5 ± 1.3 cm (range 7.5 to 10) in the external fixator group (n=7 limbs) (Morrison 2020).

In a retrospective case series of 4 adults who underwent humeral lengthening, the average lengthening achieved with the IM motorised nail was 55 mm (range 40 to 65 mm) (Furmetz 2017).

Mean lengthening time

In the retrospective case series of 9 children who had humeral lengthening (in 13 limbs), the average duration of lengthening was 114 days (range 30 to 190) in the motorised IM nail group and 103 days (range 58 to 188) in the external fixator group (Morrison 2020).

In the retrospective case series of 4 adults who underwent humeral lengthening, the average duration of lengthening was 70 days (range 52 to 95 days) (Furmetz 2017).

Mean lengthening rate (mm/day)

In the retrospective case series of 9 children who had humeral lengthening (in 13 limbs), the average lengthening per day ranged from 0.33 to 0.83 in the motorised IM nail group and 0.53 to 1.36 in the external fixator group (Morrison 2020).

Distraction and consolidation index

In the retrospective case series of 4 adults who underwent humeral lengthening, the average distraction index was 0.72 mm/day (range 0.4 to 1.0 mm/day) or 12.5 days/cm (range 8.0 to 16.2 days/cm). The mean time to reach consolidation after the distraction was 165 days. The average consolidation index was 33.6 days/cm (range 25 to 45 days/cm) (Furmetz 2017).

Safety summary

Overall complications

Overall, 33% (2/6) of patients with motorised IM nail humeral lengthening and 43% (3/7) of patients with external fixator humeral lengthening experienced complications during treatment in the retrospective case series of 9 patients who underwent humeral lengthening (in 13 limbs) (Morrison 2020).

Device-related complications

Planned IM nail redeployment (due to loss of nail fixation and deformity in 1 limb, non-compliance and slow distraction in another limb) were reported in 2 patients in the motorised IM nail group (6 limbs) in the case series of 9 patients who underwent humeral lengthening (Morrison 2020).

Implant (PRECICE IM nail) failure due to breakage of the nail crown was reported in 1 patient in the case series of 4 patients who had humeral lengthening. After consolidation, the broken nail was replaced with a technically improved nail and the course of treatment was uneventful (Furmetz 2017).

Irritation and pain penetrating the rotator cuff (caused by the cable connecting the IM nail and subcutaneous receiver) was reported in 1 patient in the case series of 4 patients who had humeral lengthening. This needed removal of the cable and receiver penetrating the rotator cuff for better range of motion (Furmetz 2017).

Bone-related complications

Premature consolidation that needed repeat IM lengthening was reported in 1 patient in the motorised IM nail group (6 limbs) in the case series of 9 patients who underwent humeral lengthening (Morrison 2020).

Extended lengthening due to improper use of the external remote control was reported in 1 patient in the IM nail group in the case series of 9 patients who underwent humeral lengthening (Morrison 2020).

Proximal migration of the humeral head resulting in reduced shoulder function was reported in 1 patient in the case series of 4 patients who had humeral lengthening. Lengthening was stopped in this patient before treatment was completed (Furmetz 2017).

Joint-related complications

Flexion contracture of the elbow which resolved with splint treatment was reported in 1 patient in the motorised IM nail group (6 limbs) in the case series of 9 patients who underwent humeral lengthening (Morrison 2020).

Reduction in elbow extension after IM nail lengthening was reported in 1 patient in the case series of 4 patients. This improved after treatment with 2 Botox injections and Z-plasty of the biceps tendon (Furmetz 2017).

Neurological complications

Transient radial nerve palsy that resolved after 14 days was reported in 1 patient in the motorised IM nail group (6 limbs) in the case series of 9 patients who underwent humeral lengthening (Morrison 2020).

Anecdotal and theoretical adverse events

In addition to safety outcomes reported in the literature, professional experts are asked about anecdotal adverse events (events which they have heard about) and about theoretical adverse events (events which they think might possibly occur, even if they have never happened). For this procedure, we received no questionnaires.

The evidence assessed

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to intramedullary distraction for lower limb lengthening. The following databases were searched, covering the period from their start to 18 May 2021: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the internet were also searched. No language restriction was applied to the searches (see the literature search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The inclusion criteria were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients with upper limb length deficiency of any aetiology.
Intervention/test	Intramedullary distraction (or distraction osteogenesis) for upper limb lengthening (implants can either be motorised nails, or magnetically driven nails).
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the IP overview

This IP overview is based on 13 patients from 2 retrospective case series.

Other studies that were considered to be relevant to the procedure but were not included in the main summary of the key evidence are listed in the appendix.

Summary of key evidence on intramedullary distraction for upper limb lengthening

Study 1 Morrison SG (2020)

Study details

Study type	Retrospective comparative case series
Country	USA (single centre)
Recruitment period	1999-2018 (1999 to 2014 external fixators, 2014-18 motorised IM nails)
Study population and number	n= 9 patients who underwent humeral lengthening (in 13 limbs). IM motorised nail lengthening (6 limbs) versus lengthening with external fixation (7 limbs) Indications for lengthening: achondroplasia (2), physeal arrest because of sepsis or trauma (9), brachial plexus palsy (1), and unicameral bone cyst (1). Upper limb length discrepancy (LLD): IM motorised nail group (range 4-9 cm); external fixation group (range 7-13 cm). Side: 6 left, 7 right
Age and gender	Mean age: IM motorised nail group 15.4 (range, 13 to 17.7); external fixation group 13.4 years (range, 6.9 to 18.1) gender: 5 male, 4 female
Study selection criteria	Inclusion criteria: patients who underwent humeral lengthening with use of external fixation and the use of an IM motorised nail for lengthening. Exclusion criteria: patients with less than 6 months follow up from index lengthening were excluded.
Technique	Motorised IM lengthening using the PRECICE nail (in 6 limbs): retrograde nail insertion was done in all cases. 2 modifications were done in nailing technique and both were on an off-label basis. In one technique, 4 nails were modified (shortened at either or both ends) as the humeral length was too short in patients. In another technique, another nail redeployment was done so that a greater lengthening may be achieved with the same implant. Lengthening with external fixation (in 7 limbs): circular external fixator (Ilizarov, or Taylor Spatial Frame), mono-lateral rail fixator (MRF-Orthofix), or mono-lateral multiplanar were used. All external fixators were removed under general anaesthetic after treatment. One patient had bilateral lengthening. In 2 limbs external fixation was used for the first lengthening and second lengthening was done with 1 or 2 IM motorised nails. The rate of distraction was adjusted on the basis of radiographic parameters.

Follow up	6 months
Conflict of interest/source of funding	Authors declare that they have no conflicts of interest. Some authors received fees from the company outside the submitted work.

Analysis

Study design issues: a small study with few patients; data was collected retrospectively; procedures were performed by a single surgeon in one centre. The lengthening rate was averaged over the entire distraction period for the purposes of study. Complications were recorded and graded using the Clavien-Dindo classification (grade I-V); there were no patient reported outcomes.

Study population issues: patients were mainly paediatric population comparable between groups.

Other issues: Angular deformity corrections were also done in 5 limbs (2 in IM nail group and 3 in external fixator group). Two patients had removal of previously placed humeral plates. One patient had concurrent femoral lengthening with an IM motorised nail while using an external fixator for the humeral lengthening.

Key efficacy findings

- Number of patients analysed: 9

  13 limbs (6 with IM motorised nail versus 7 with external fixation)

Clinical outcomes

	IM nail group (6 limbs)	**External fixation (7 limbs)**
Preoperative humeral length, cm	range 23.3 -31	range 12- 25.6
Mean absolute lengthening achieved, cm	6.6 ± 2.3 (range 1 - 9)	8.5 ± 1.3 (range 7.5 - 10)
Mean percentage lengthening	29% (range 4 - 57%)	52% (range 30-67%)
Average duration of lengthening, days	114 (range 30-190)	103 (range 58-188)
Average lengthening/day, mm	range 0.33 – 0.83	range 0.53 -1.36
Average duration of external fixation time, days	-	215

Key safety findings

Complications	**IM motorised nail group (6 limbs)**	**External fixation (7 limbs)**
Total complications	**33% (2/6)**	**43% (3/7)**
Planned IM nail redeployment (due to loss of nail fixation and deformity in 1 [grade III], noncompliance and slow distraction in 1 [grade I])	2	-

Flexion contracture of the elbow (grade II, resolved with splint treatment)	1	-
Premature consolidation (grade II, needed repeat IM lengthening)	1	-
Transient radial nerve palsy (grade I, resolved after 14 days)	1	-
Extended lengthening (due to improper use of external remote)	1	
Second lengthening (with IM nail after initial external fixation)	0	2
Pin-site infections (2 managed with antibiotics and 1 needed reoperation for removal and new pin insertion) (grade I, II, III)	0	3
Loss of fixator frame position (realigned in clinic) (grade II)	-	2
Multiple tethered pin-site scar revision (released 2 years after fixator removal) (grade III)	-	1
Automator malfunction (grade I)	-	1

Study 2 Furmetz J (2017)

Study details

Study type	Retrospective case series
Country	Germany, Denmark (2 centres)
Recruitment period	2012-15
Study population and number	N=4 patients with limb length discrepancy who had intramedullary lengthening of the humerus (5 procedures) Indications for lengthening: posttraumatic shortening of the humerus after complex fracture (n=1), traumatic growth arrest in childhood (n=1), unilateral humeral shortening caused by Erb–Duchenne-type obstetric palsy (n=2). Side: 3 left, 1 right
Age and gender	Age range 19 to 51 years; 3 men and 1 woman.
Study selection criteria	Not reported
Technique	IM lengthening was done with 2 different fully implantable lengthening devices (FITBONE and PRECICE). Two different approaches and implantation techniques were used. 3 patients were treated with FITBONE IM nail by an antegrade approach (3 procedures); 1 patient had lengthening with a PRECICE IM nail and a retrograde approach (2 procedures). Physiotherapy was carried out on a regular basis.
Follow up	6 months after nail removal (in 3 patients) 18 months after nail implantation (in 1 patient)
Conflict of interest/source of funding	The authors declare no conflict of interest. No financial support or grants were received for this study.

Analysis

Study design issues: small sample size, clinical and radiographic data were retrospectively reviewed.

Study population issues:

Key efficacy findings

- Number of patients analysed: 4

Clinical outcomes

Average nail lengthening, mm	55 mm (range 40–65 mm)
Average duration of lengthening, days	70 days (range 52–95)
Average distraction index, mm/day	0.72 mm/day (range 0.4–1.0 mm/day) or

	12.5 days/cm (range 8.0–16.2 days/cm).
Mean time to reach consolidation after the distraction	165 days
Average consolidation index	33.6 days/cm (range 25–45 days/cm)

Range of motion:
In 3 patients with antegrade lengthening, reduced range of motion in adjacent joints (decreased shoulder abduction but no change in elbow motion) was reported. In 1 patient with the retrograde approach shoulder abduction and flexion improved but elbow extension decreased marginally.

Patient satisfaction
All patients reported they were satisfied with the outcome. Patients reported reduced neck pain and improved function in performing daily activities (such as clothing and personal hygiene, resting arms at the table), using computer and bicycle.

Key safety findings

Complications

Adverse event	n
Irritation and pain penetrating the rotator cuff (caused by the cable connecting the nail and subcutaneous receiver), needed removal	1
Proximal migration of the humeral head and reduced shoulder function (lengthening was stopped)	1
Reduction in elbow extension (treated with 2 Botox injections, Z plastic of the biceps tendon)	1
Implant (PRECICE IM nail) failure due to breakage of the crown (after consolidation, the nail was replaced with a technically improved nail and the course of treatment was uneventful).	1

Validity and generalisability of the studies

- Two different intramedullary limb lengthening devices (motorised nails, and magnetically driven nails) with variation in techniques were used for distraction and stimulating upper limb lengthening.

- There are no randomised controlled trials comparing the use of intramedullary limb lengthening nails for upper-limb lengthening with current standard of care/conventional lengthening procedures (external fixation devices).

- Evidence is limited and mainly based on 2 small case series that are prone to a number of biases. One case series compared motorised internal humeral lengthening to external fixator humeral lengthening.

- There is very limited data on bilateral lengthening and the case mix is very heterogenous with no patient reported outcomes.

Existing assessments of this procedure

There were no published assessments from other organisations identified at the time of the literature search.

Related NICE guidance

Interventional procedures

- Intramedullary distraction for lower limb lengthening. NICE Interventional procedures guidance IPG197 (2006). Available from http://www.nice.org.uk/guidance IPG197

  This guidance is currently under review and is expected to be updated in 2021. For more information, see http://www.nice.org.uk/guidance/IPG197

Additional information considered by IPAC

Professional experts' opinions

Expert advice was sought from consultants who have been nominated or ratified by their professional Society or Royal College. The advice received is their individual opinion and is not intended to represent the view of the society. The advice provided by professional experts, in the form of the completed questionnaires, is normally published in full on the NICE website during public consultation, except in circumstances but not limited to, where comments are considered voluminous, or publication would be unlawful or inappropriate. No professional expert questionnaires for intramedullary distraction for lower limb lengthening were submitted.

Patient commentators' opinions

NICE's Public Involvement Programme will send questionnaires to NHS trusts for distribution to patients who had the procedure (or their carers). When NICE has received the completed questionnaires, these will be discussed by the committee.

Company engagement

A structured information request was sent to 2 companies who manufacture a potentially relevant device for use in this procedure. NICE received 2 completed submissions. This was considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

Issues for consideration by IPAC

References

1. Morrison SG, Georgiadis AG, Dahl MT. (2020) Lengthening of the humerus using a motorized lengthening nail: a retrospective comparative series. Journal of pediatric orthopedics. 2020;40:e479–e486.
2. Furmetz J, Kold S, Schuster N et al. (2017) Lengthening of the humerus with intramedullary lengthening nails—preliminary report. Strategies in Trauma and Limb Reconstruction,12:99–106.

Literature search strategy

Databases	Date searched	Version/files
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	18/05/2021	Issue 5 of 12, May 2021
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	18/05/2021	Issue 4 of 12, April 2021
International HTA database (INAHTA)	18/05/2021	-
MEDLINE (Ovid)	18/05/2021	1946 to May 17, 2021
MEDLINE In-Process (Ovid)	18/05/2021	1946 to May 17, 2021
MEDLINE Epubs ahead of print (Ovid)	18/05/2021	1946 to May 17, 2021
EMBASE (Ovid)	18/05/2021	1974 to 2021 May 17

Literature search strategy

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

exp Orthopedic Fixation Devices/
((Intramedullar* or internal* or implant*) adj4 (lengthen* or distract*)).tw.
ISKD.tw.
intramedullary skeletal kinetic distractor.tw.
((orthopaed* or external*) adj4 fixat*).tw.
ilizarov technique/ or osteogenesis, distraction/
(ilizar* adj4 techniq*).tw.
(distract* adj4 osteogenes*).tw.
(albizia* or albizzia).tw.
or/1-9
Bone Lengthening/
Bone Malalignment/
(bone* adj4 (lengthen* or malformat* or malalign*)).tw.
or/11-13
Humerus/
humer*.tw.
Radius/
radius.tw.
Ulna/
ulna.tw.
Arm/
arm.tw.
Upper Extremity/
(upper* adj4 (extremit* or arm* or limb*)).tw.
or/15-24
14 and 25

((Arm* or upper limb or upper arm or ulna or radius* or humer*) adj4 (lengthen* or elongat* or extend*)).tw.
26 or 27
10 and 28
precice.tw.
illzarov.tw.
Intramedullary skeletal kinetic distractor.tw.
Albizzia nail.tw.
fitbone.tw.
or/30-34
29 or 35
Animals/ not Humans/
36 not 37
limit 38 to ed=20200901-20210531

Appendix

The following table outlines the studies that are considered potentially relevant to the IP overview but were not included in the summary of the key evidence. It is by no means an exhaustive list of potentially relevant studies.

Additional papers identified

Article	Number of patients/follow up	Direction of conclusions	Reasons for non-inclusion in summary of key evidence section
Kurtz AM, Rozbruch SR. (2017) Humerus Lengthening with the PRECICE internal lengthening nail. J Pediatr Orthop; 37: e296–e300.	Case report A 15-year-old girl with humeral shortening secondary to proximal humeral growth disturbance following treatment for a unicameral bone cyst was treated with humeral osteoplasty and gradual lengthening with an off-label use of a fully implantable motorised intramedullary lengthening nail.	Humeral lengthening (5 cm) was achieved at 9 weeks, with bony union at 7 months, and hardware removal at 9½ months. Shoulder and elbow motion was maintained during and after treatment.	More relevant studies included in the summary of key evidence.
Lee FY, Schoeb JS, Yu J, et al. Operative lengthening of the humerus: indications, benefits, and complications. J Pediatr Orthop. 2005;25:613–616.	Case series N=16 (only 1 patient had humeral lengthening over a retrograde intramedullary nail).	The benefits from humeral lengthening include increased performance in daily activities, improved sports performance, and significantly better self-image. Complications included temporary radial nerve palsy in 3 cases, drainage from the pin tracts in 2 cases, elbow flexion contracture in 3 cases, and late humerus fracture in 2 cases. All the	15 humeral lengthening procedures were done using external fixators which is out of the scope of this overview.

		complications resolved over time and did not affect the outcome.	
Paley D (2015) PRECICE Intramedullary limb lengthening system. Expert Rev Med Devices 12:231–249	Retrospective case series n= 65 patients with limb length discrepancy (unilateral) and short stature (bilateral) underwent IM lengthening with Precice nails. Different nail locations reported including 1 humerus lengthening.	Successful lengthening was achieved in all patients. There were numerous distraction and hardware complications.	Only 1 patient with a humerus lengthening was included in this study.
Tiefenboeck TM, Zak L, Wozasek GE. (2016) Intramedullary magnetically actuated limb lengthening in a patient with congenital humeral limb shortening. Injury, Int. J. Care Injured 47, 1597–1600.	Case report 32 year old female patient with congenital shortening had intramedullary magnetic limb lengthening.	The telescopic device presents a promising tool for humeral limb lengthening with excellent outcome at short-term.	Larger studies included in table 2.
Zak L, Tiefenboeck TM, Wozasek GE. (2019) Innovative technique in extended intramedullary humeral lengthening. JBJS Case Connector 9 d (3 d) :e0174	Case report IM nailing technique with unlocking, backwinding, and reinterlocking of the telescopic nail (Precice nail) for extended humeral distraction.	A middle-aged patient with a short right humerus secondary to a childhood growth plate injury underwent successfully lengthening with an off-label application of a tibial distracting device.	Larger studies included in table 2.