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Advancing Paediatric Ultrasound Imaging: A Novel Hybrid High -Frequency Transducer Bridging Linear and Hockey Stick Designs.

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Introduction (Background)

① L3-22 is High Frequency, 26mm Linear probe, particularly appropriate for ultrasound scans of: Superficial areas of concern, such as detailed MSK scans, lumps and bumps, thyroid, evaluation of lymph nodes in adults and children. [1]

② In paediatrics this is particularly useful for abdominal examinations, from neonates to infancy, vascular scans and hip scans until the early childhood. According to the criteria of the US National Institute of Child Health and Human Development (NICHD), paediatrics is divided into eight age groups (Table 1). After the age of 12, diagnosis is made using probes identical to those used in adults. [2]

③ However, cooperation for the examination can be difficult for newborns to children under the age of 2.

④ Therefore, a Linear product, L3-22, was developed for quick and accurate scans.

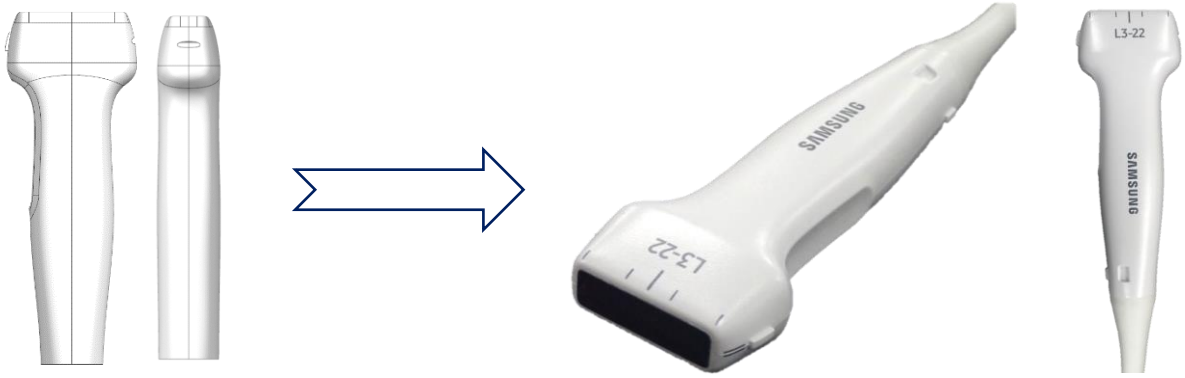
⑤ This white paper will explore the clinical utility and superior image quality of the L3-22.

Stage	Definitions
Preterm Neonatal	The period at birth when a newborn is born before the full gestational period
Term Neonatal	Birth~27D
Infancy	28D~12M
Toddler	13M~2Y
Early Childhood	2~5Y
Middle Childhood	6~11Y
Early adolescence	12~18Y
Late adolescence	19~21Y

Paediatric Linear Probe - L3-22

Ergonomically designed Probe

Ergonomically designed Probe Head and Designed by minimizing probe side thickness.



Design concept

L3-22

Materials and Methods

We have conducted a series of clinical trials using the L3-22 on patients up to the age of 16 and compared the images with other probes. The trials have been designed to test the probe's effectiveness in diagnosing various conditions.

Case Study

The L3-22 proved to be a valuable tool in diagnostic paediatric ultrasound at Birmingham Children's Hospital, Radiology Department.

Advantages of L3-22 from the perspective of Image Quality, Footprint, and Ergonomics.

① Image Quality: Facilitate accurate diagnosis through high-resolution imaging

② Footprint: Enhance usability in various paediatric case with its small and straight-shaped design.

③ Ergonomics: Improve user-friendliness with an ergonomic design for enhanced convenience for paediatric (under 2 years old) diagnostics.

The case studies have been conducted at Department of Ultrasound in Radiology at Birmingham Children's Hospital NHS Foundation Trust, Steel house Lane, Birmingham B4 6NH, UK. Experienced Senior Paediatric Sonographers performed baseline images according to our local protocols from a dedicated ultrasound machine (RS85 Prestige, Samsung Medison Co., Ltd., Korea) using various probes. Areas of concern were identified and subsequently examined with the new 3-22 MHz High Frequency linear transducer (L3-22, Samsung Medison Co., Ltd., Korea).

Table 2. shows the main cases of ultrasound diagnosis in infants, toddlers and middle childhood.

under 2 years old	under 17 years old
1. Pyloric Stenosis (18 days old) 2. Superior Sagittal Sinus Thrombosis - Neonatal Neurosonography (4-week-old) 3. Hydronephrosis (22 months)	4. Appendicitis 4a (5 years old), 4b (13 years old) 5. DVT assessment (14 years old)

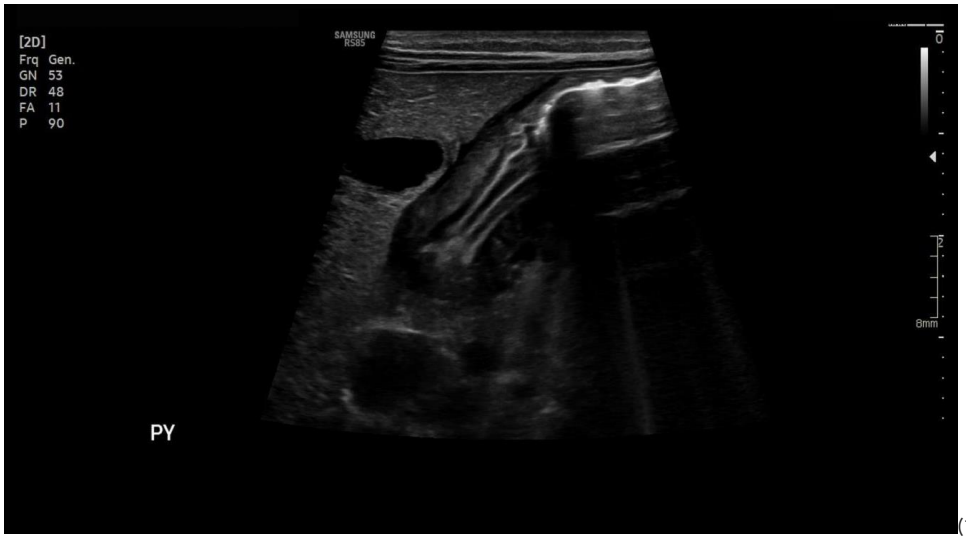
Table 2. Types of main cases of ultrasound diagnosis for infants, toddlers and middle childhood

Case 1

An eighteen days old, full-term baby was presented to Accident & Emergency (A&E) with episodes of projectile vomiting, jaundice and unable to tolerate feeds. The L3-22 is High Frequency and was used to investigate the cause of vomiting. Ultrasound is the modality of choice in the right clinical setting with a sensitivity of 97% and specificity of 100%. [3] Identifying the pylorus longitudinally and transversely is a crucial part of the examination as it enables the operator to take accurate measurements of the muscle thickness. [2] [3] On examination single pyloric muscle thickness =5.1mm, pylorus canal length =21 mm, and transverse diameter of pylorus = 15 mm. Using Table 3, the ultrasound appearances, measurements, and the absence of gastric opening over 20 minutes provided a diagnosis of hypertrophic pyloric stenosis. [3] [4] [5] This was also correlated with clinical symptoms and the patient had a corrective surgical pyloromyotomy.

Single muscle wall thickness (not including mucosa or pyloric canal)	3 mm
Canal length	16 mm
TS diameter	11 mm

Table 3. Recommended upper limits of normal measurements for assessment of pyloric stenosis [4]

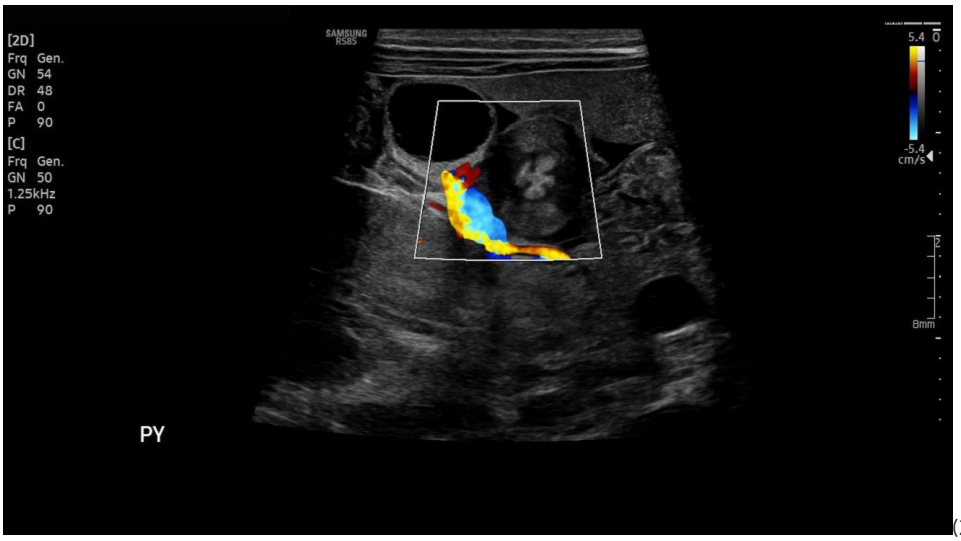


(1a)

(1b)

Fig. 1a. Confirmation of Hypertrophic pyloric stenosis (HPS)

Fig. 1b. Pyloric muscle measurements (Pylorus Length = 21mm, transverse diameter=15mm)



(2a)

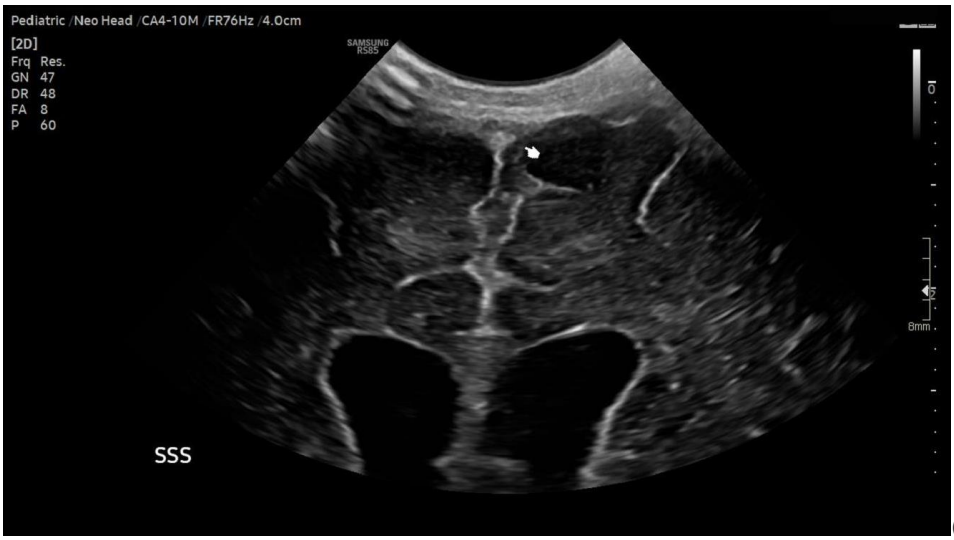
(2b)

Fig. 2a. 2b. Transverse image of the pylorus with the typical target sign. (Pylorus Single Muscle Thickness=5.1mm)

This case demonstrates how improved ultrasound image quality in acutely unwell infants using the L3-22 probe can support an early diagnosis, enabling rapid corrective treatment with the potential of improved patient outcome.

Case 2

A four-week-old ex –premature baby (35/40) was referred for neonatal neurosonography evaluation of the brain, following cardiac arrest at home with no underlying cause to rule out any possible aetiology. [7][8] Echogenic material was seen with the curvilinear probe within the superior sagittal sinus, so further evaluation was required with the L3-22 High Frequency probe, as thrombosis in the superior sagittal sinus thrombosis has been associated with dehydration, sepsis, and ischemia. [9]



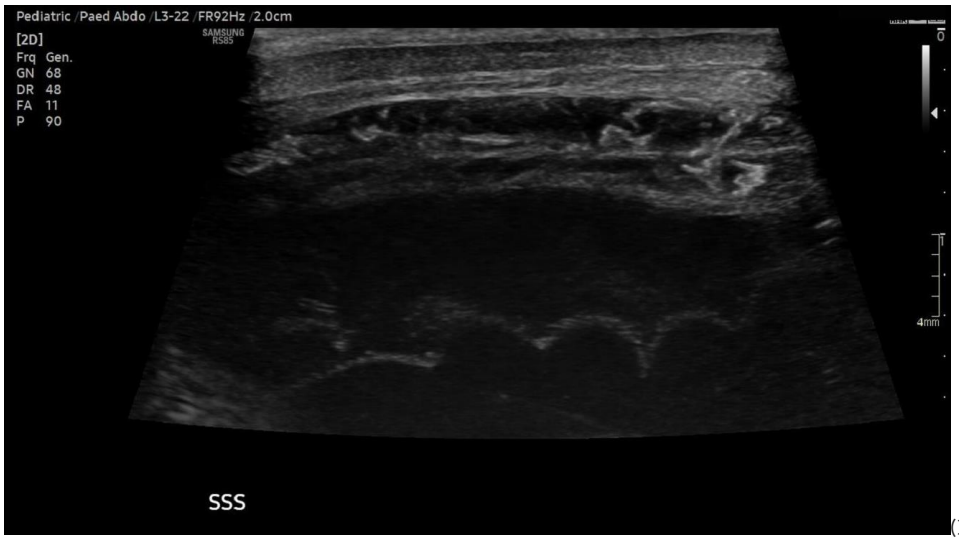
(3a)

Fig. 3a. Echogenic material seen with a curvilinear probe within the superior sagittal sinus, which was confirmed on superior quality images (see below Fig. 3b & Fig. 3c).

(3b)

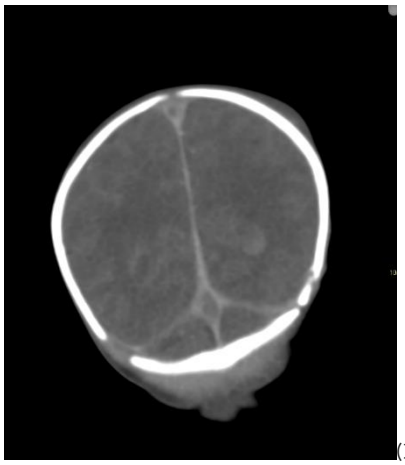
(3c)

Fig. 3b. 3c. Occlusive thrombus confirmed with L3-22 High Frequency probe on B-mode and colour Doppler within the superior sagittal sinus.



(3d)

Fig. 3d. Illustrates the extensive thrombus in a sagittal plane.


(3e)


(3f)

Fig. 3e. 3f. Confirmed on CT venogram, however the thrombus is better visualised with the L3-22 High Frequency probe with direct comparison with the images above in the same plane.

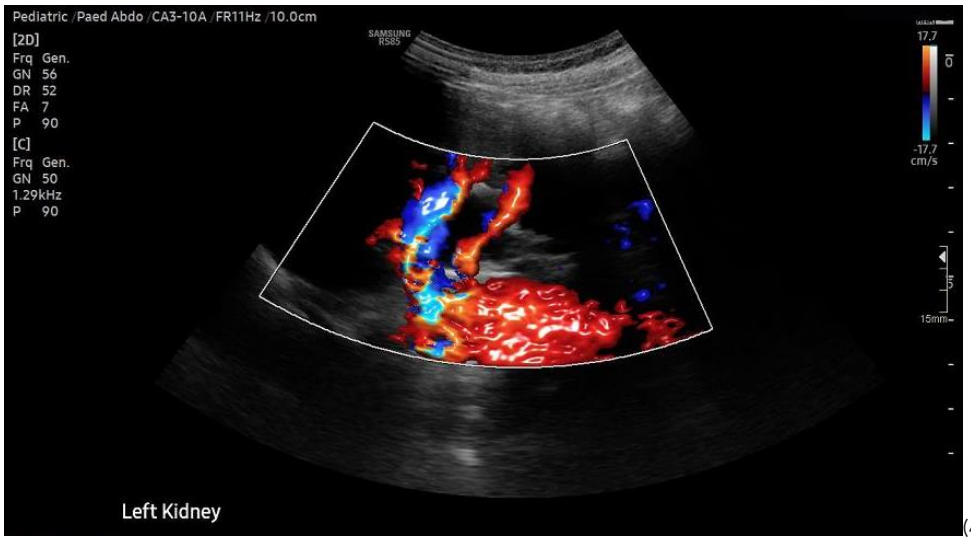
This case demonstrates how improved ultrasound image quality using the L3-22 probe in very clinically unwell infants can assist in early diagnosis, support further imaging if necessary, enabling early intervention and treatment with the potential of improved patient outcome.

Case 3

A twenty-two-month-old, presented with hydronephrosis, as a specialist paediatric centre, we often perform second opinion scans or repeat scans to further evaluate the initial diagnosis. On ultrasound assessment at our centre, there was noted to be a pelviureteric junction obstruction (PUJO), which is the most common cause of congenital urinary tract obstruction. [3] Obstruction can be due to an intrinsic stenosis of the proximal ureter; however, it can be caused by extrinsic factors including aberrant crossing blood vessels. [3][10][11]

On examination the sonographer identified an aberrant crossing vessel at the pelviureteric junction which was a possible cause for the PUJO. [10][11]

(4a)

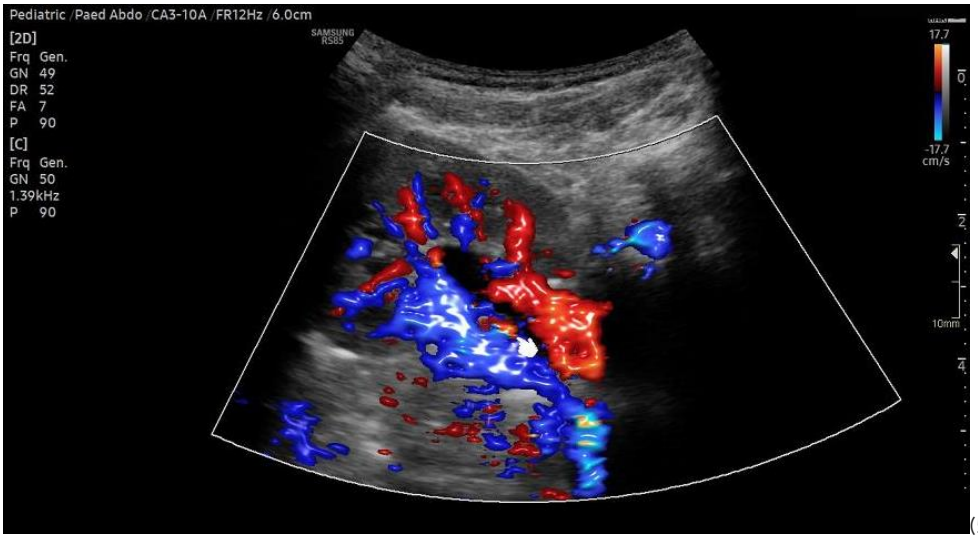


(4b)

Fig. 4a. Shows left hydronephrosis using the CA3-10A curvilinear probe in supine.

Fig. 4b. On colour Doppler an aberrant, accessory, lower pole segment vessel is found and observed to compress the pelviureteric junction, raising the possibility of a crossing vessels obstruction

(5a)



(5b)

Fig. 5a. Crossing vessels confirmed on B-mode on L3-22 High Frequency probe.

Fig. 5b. Confirmation seen on colour Doppler.

This case demonstrates how improved image quality using the L3-22 probe can assist in the diagnosis of PUJO obstruction, with the presence of an aberrant crossing vessel which may be the extrinsic obstructive cause. This assists the surgeon when planning corrective surgery to relieve the obstruction.

Case 4(a)

A four-year-old patient presented to A&E with 11 days history of abdominal pain and vomiting. On examination, the paediatric surgical team suspected right Iliac fossa (RIF) fullness and referred the patient for an urgent ultrasound scan to look for the cause. Pain in the right lower abdomen is a common clinical presentation in children, and accurate clinical diagnosis remains challenging due to the diverse clinical causes for pain. [12] Acute appendicitis is the most common abdominal surgical emergency in children.[13] Ultrasound is the first-line imaging modality for children with suspected acute appendicitis with high levels of accuracy, reducing the need for further imaging. [12][13][14]

The diagnosis of acute appendicitis often presents a challenge, despite the high instance of occurrence. The classic presenting of periumbilical pain, anorexia, nausea, vomiting, guarding, and migration of pain to the right lower quadrant are not always present, and children under 5 years of age often present with atypical symptoms.

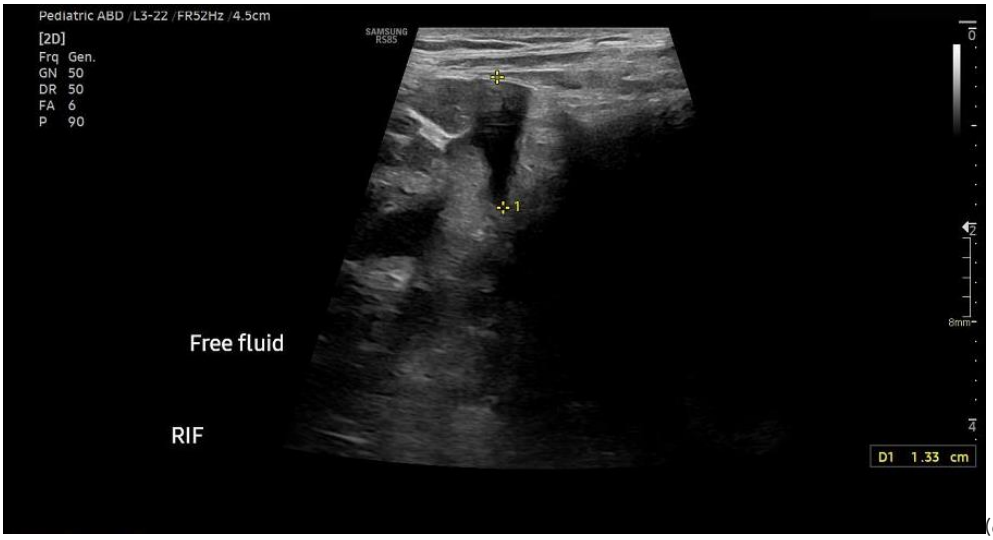
[13] As a result, presentation and diagnosis of acute appendicitis in children under 5 may be delayed, contributing to a higher rate of perforated appendicitis in this cohort of patients. [13]

(6a)

(6b)

Fig. 6a. Shows a 5.5 cm heterogeneous collecting using the CA3-10A curvilinear probe, measuring 5.5 cm.
Fig. 6b. Confirmation of a heterogeneous mass in the RIF using L3-22 High Frequency probe. An appendicolith with strong acoustic posterior shadowing is seen. Ultrasound findings are consistent with a perforated appendicitis with an associated periappendiceal collection and an appendicolith within.

(6c)

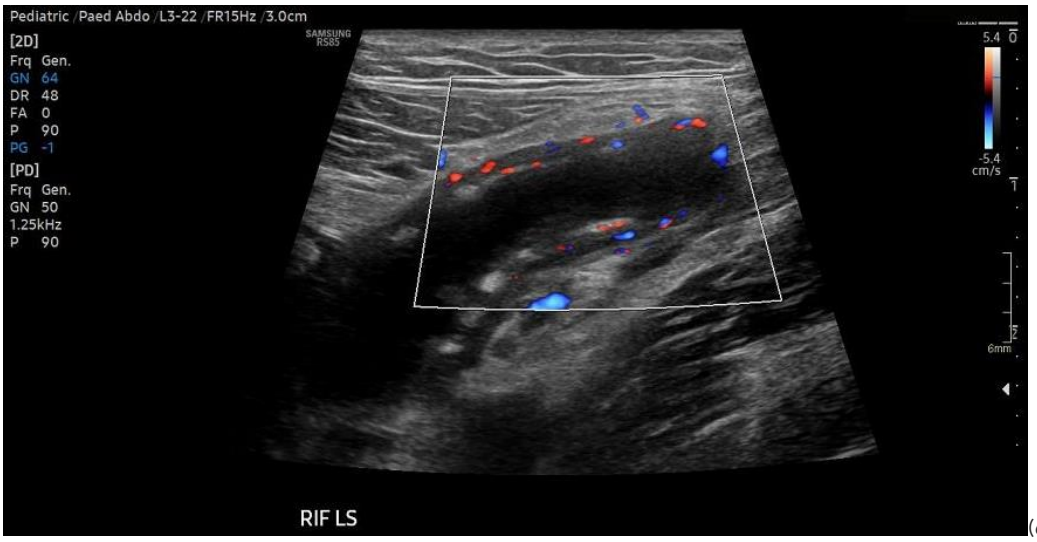


(6d)

Fig. 6c. 6d. Demonstrates presence of mesenteric lymph node and free fluid, adjacent to the collection that could not be seen with the CA3-10A curved probe.

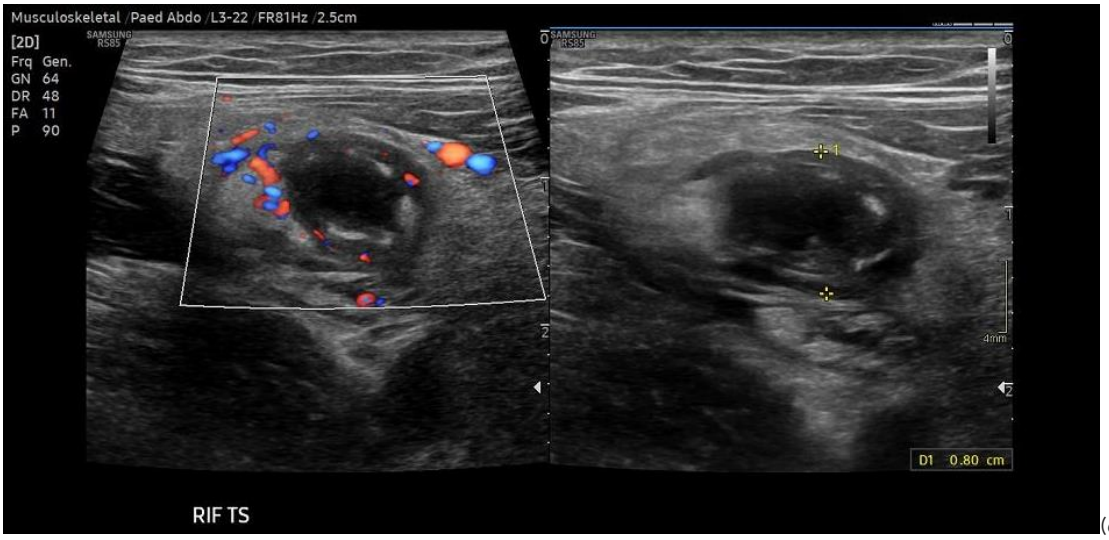
Case 4(b)

A thirteen-year-old presented to A&E with symptoms of vomiting and diarrhea and acute pain within the last 24 hours.



(6e)

Fig. 6e. The ultrasound image depicts the right iliac fossa (RIF) in a teenager patient, using color Doppler imaging. The longitudinal view (LS) captures a tubular structure, which appears dilated and surrounded by echogenic fat, indicating inflammation. The color Doppler shows increased blood flow in the wall, consistent with hyperemia, a common finding in active inflammation. The structure's non-compressibility further points towards appendiceal pathology, as normal bowel loops tend to collapse under pressure.
The surrounding tissue exhibits increased echogenicity, consistent with peri-appendiceal fat stranding. This is secondary to surrounding inflammation, reinforcing the suspicion of acute appendicitis.



(6f)

Fig. 6f. The ultrasound image shows a transverse view (TS) of the right iliac fossa (RIF), of the above acute appendicitis. The appendix is dilated measuring 8 mm in diameter, upper limits of normal appendix diameter 6-7mm. [3][12] The TS images confirm a noncompressible tubular structure, with hyperaemia and surrounding echogenic fat, consistent with inflammation.

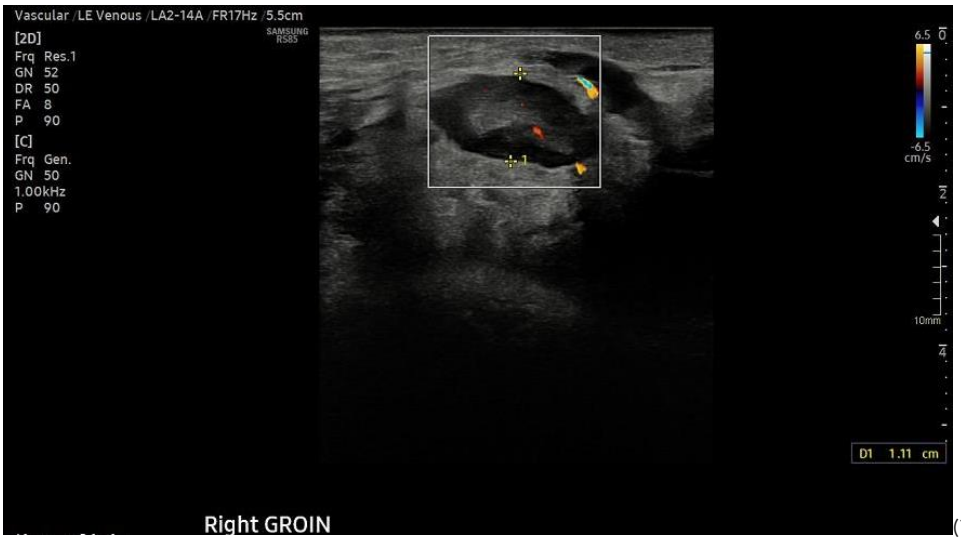
Cases (4a and 4b) demonstrate the superior imaging obtained using the L3-22 High Frequency probe, in cases of appendicitis in 2 children aged 4 and 13 years. The ultrasound images supported the diagnosis of perforated appendix and the presence of an appendicolith in 4a, and appendicitis in 4b, both of which were confirmed on laparoscopic surgery.

Case 5

A fourteen-year-old patient with a background of 22q11 deletion syndrome and complex cardiac and neurological background, who underwent aortic and pulmonary valves replacement surgery five days prior to the ultrasound scan. The indication given was to rule out deep vein thrombosis (DVT) as the patient developed swelling in the right lower leg. [15] DVT in the paediatric population is rare but has potentially serious consequences such as pulmonary embolism and post-thrombotic syndrome, so early and accurate diagnosis is essential. [16]

Additional information obtained at the time of examination was that the patient had an emergency venous cut down procedure to expose and cannulate a vein for immediate intravenous (IV) access during his recent cardiac surgery. [17] Although most incidences of DVT in children are associated with central venous catheterization, there are many other risk factors to consider in paediatrics including surgery and trauma. [16] In paediatric patients with DVT, symptom development is often subtle with the most commonly reported symptom being unilateral limb swelling as reported in this case. [16] Ultrasound is the first line imaging modality in cases of suspected DVT so an urgent ultrasound was clinically indicated in this case.

A full venous assessment was performed of the right leg using B mode with color and spectral ultrasound and there was no evidence of a DVT, so the examination was extended to try to identify other causes for unilateral leg swelling. Lymph nodes are frequently seen in paediatric patients and appear as oval hypoechoic structures with an echogenic linear hilum which demonstrates vascularity on colour Doppler as seen on Fig. 7a. [3]

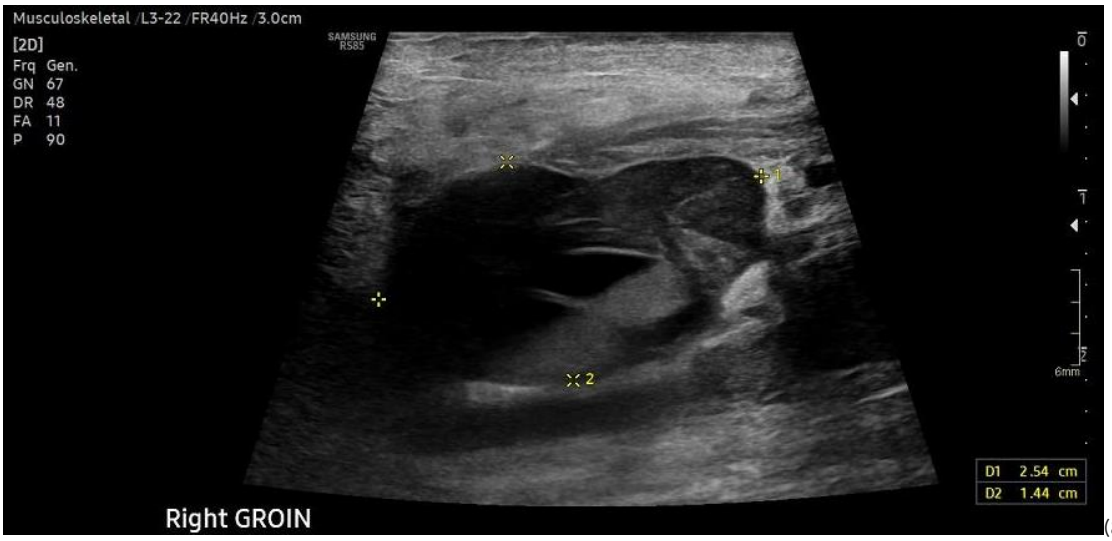


(7a)

(7b)

Fig. 7a. 7b. After a normal DVT assessment, the patient was asked to localize the source of pain and indicated the right roin. The superficial area of swelling correlated to a morphologically normal lymph (Fig. 7a) with a trace of free fluid around it.

(a); The free fluid was then further examined in an attempt to further characterise and determine the origin; the free fluid was seen to extend into an abnormal heterogeneous collection which contained echogenic contents (Fig. 7b and Fig. 8a).



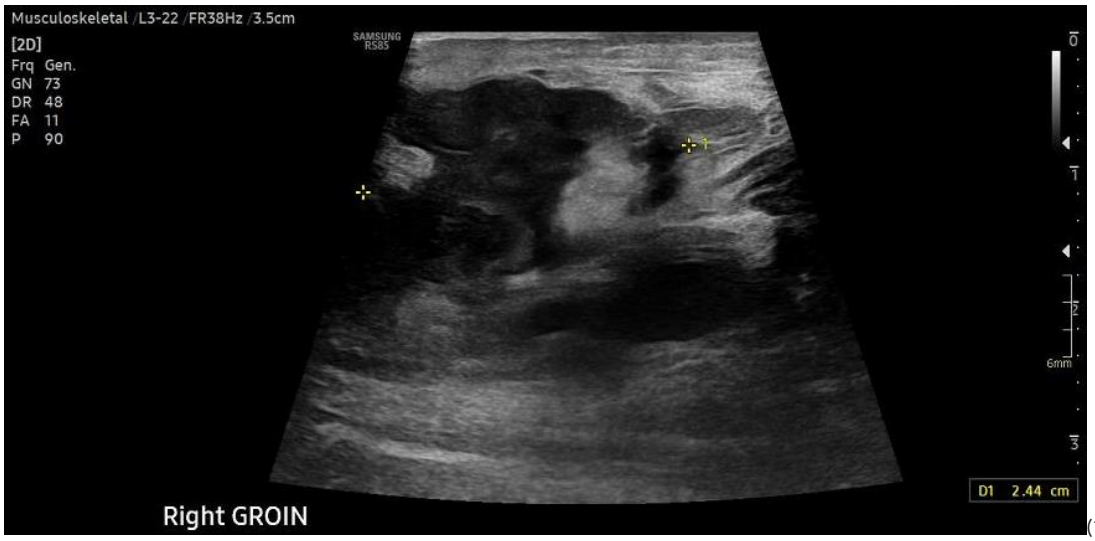
(8a)

Fig. 8a. Due to limited access caused by surgical dressings, the L3-22 was used to assess the superficial area of concern and further evaluate the above findings (7b) and a large well defined heterogeneous collection measuring 2.5 cm x 1.4 cm was seen.[16] The ultrasound appearances [3][18] and clinical history gave a preferred diagnosis of post operative haematoma following an emergency venous cut down procedure during cardiac surgery.

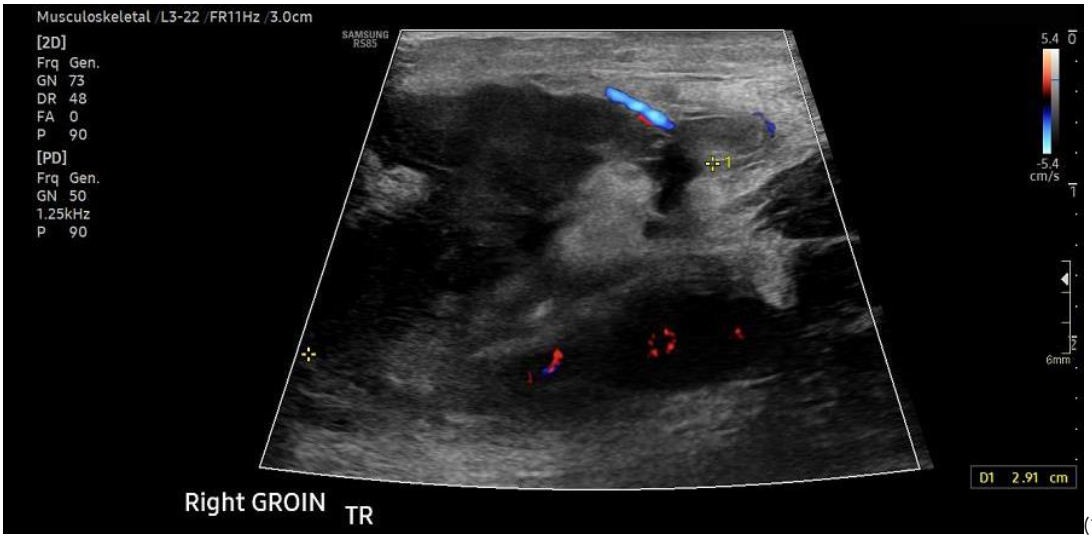
(9a)

(9b)

Fig. 9a. In the longitudinal plane the above '2.5 cm x 1.4 cm' haematoma when was elongated appear to have a deeper and larger extension measuring 3.9 cm x 1.7 cm. No vascularity detected within (Fig. 9b).

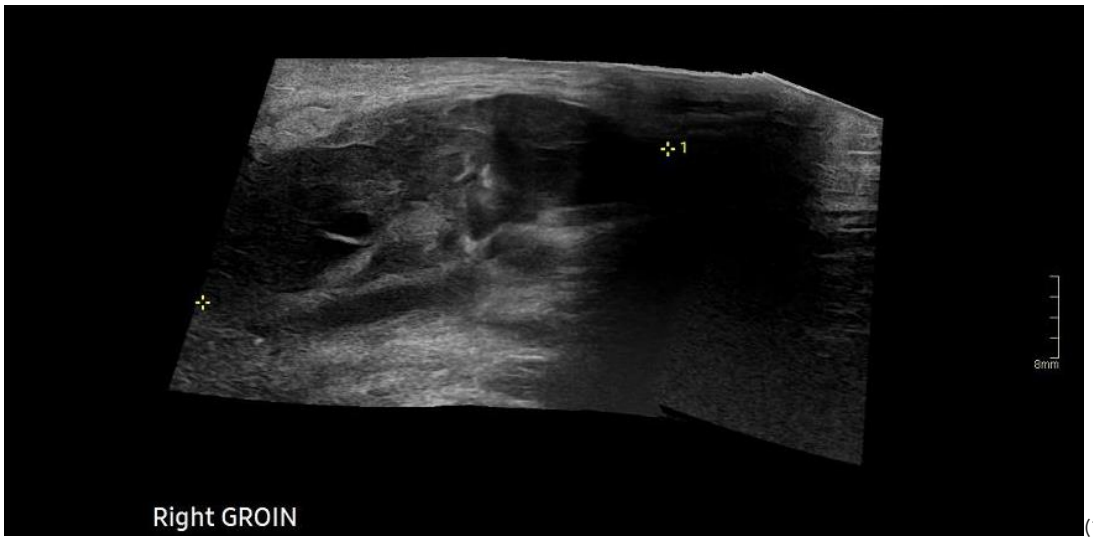


(10a)



(10b)

Fig. 10a. 10b. Illustrate the large extension of the haematoma in the transverse plane with areas of anechoic and echogenic changes suggestive of a recent large haemorrhage post the emergency 'cut down' procedure.



(11a)

Fig. 11a. Demonstrates the extent of the haematoma using with the panoramic setting, revealing that the initial cystic haematoma measuring 2.5 cm x 1.4 cm (Fig. 8a)

This case demonstrates how a DVT was excluded and the cause for pain and leg swelling was diagnosed on ultrasound examination using the Samsung L3-22 High Frequency probe. The smaller footprint and superior image quality enabled the operator to reach an area that was not previously accessible and enabled a more accurate diagnosis excluding the need the further imaging investigations.

Conclusion

This paper demonstrates the superior image quality of the Samsung L3-22 Probe in paediatric ultrasound with the additional benefit of improved ergonomics and smaller footprint for improved accessibility.
We anticipate that our findings will highlight the importance of utilizing the specialised L3-22 for focused assessments of areas of concern in paediatric diagnostic ultrasound. In our experience as a busy specialist paediatric tertiary referral centre, the L3-22 probe provides superior image quality and increased diagnostic confidence.

References

[1] Ultra-high-frequency ultrasound of superficial and musculoskeletal structures in the pediatric population, Pediatr Radiol. doi: 10.1007/s00247-021-04978-0. 2021 March 05.

[2] Standard 6: Age Groups for Pediatric Trials, PEDIATRICS. doi: 10.1542/peds.2012-0055I. 2012 June 01.

[3] Siegel MJ. Pediatric sonography. Lippincott Williams & Wilkins; 2018 Oct 1.

[4] De Bruyn R, editor. Pediatric Ultrasound E-Book: Pediatric Ultrasound E-Book. Elsevier Health Sciences; 2010 Jun 17.

[5] Hernanz-Schulman M. Pyloric stenosis: role of imaging. Pediatric radiology. 2009 Apr;39(Suppl 2):134-9.

[6] Liu ZQ, Li QL, Liu JB, Liu HF, Ye H, Fang Y, Zhou PH. Peroral pyloromyotomy for the treatment of infantile hypertrophic pyloric stenosis. Endoscopy. 2020 Apr;52(04):E122-3.

[7] Caro-Domínguez P, Lecacheux C, Hernandez-Herrera C, Llorens-Salvador R. Cranial ultrasound for beginners. Translational Pediatrics. 2021 Apr;10(4):1117.

[8] Horsch S, Schwarz S, Arnaez J, Steggerda S, Arena R, Govaert P, EurUS. Brain group, Agut T, Alarcon A, Bartocci M, Benavente-Fernández I. Cerebral Doppler imaging in neonates: A guide for clinical application and diagnosis. Developmental Medicine & Child Neurology. 2024 Jun 28.

[9] Thomson GD, Teele RL. High-frequency linear array transducers for neonatal cerebral sonography. American Journal of Roentgenology. 2001 Apr;176(4):995-1001.

[10] Villemagne T, Fourcade L, Camby C, Szwarc C, Lardy H, Leclair MD. Long-term results with the laparoscopic transposition of renal lower pole crossing vessels. Journal of Pediatric Urology. 2015 Aug 1;11(4):174-e1.

[11] Veyrac C, Baud C, Lopez C, Couture A, Saguintaah M, Averous M. The value of colour Doppler ultrasonography for identification of crossing vessels in children with pelvi-ureteric junction obstruction. Pediatric radiology. 2003 Nov;33:745-51.

[12] Desoky SM, George M, Epelman M, Frush DP, Gourlay DM, Moore MM, Schooler GR, Towbin AJ, Udayasankar U, Zukowski M, Callahan MJ. Imaging of Right Lower Quadrant Pain in Children and Adolescents: AJR Expert Panel Narrative Review. American Journal of Roentgenology. 2023 Jun 23;220(6):767-79.

[13] Koberlein GC, Trout AT, Rigsby CK, Iyer RS, Alazraki AL, Anupindi SA, Bardo DM, Brown BP, Chan SS, Chandra T, Dillman JR. ACR appropriateness criteria® suspected appendicitis-child. Journal of the American College of Radiology. 2019 May 1;16(5):S252-63.

[14] Hayatghaibi SE, Trout AT, Dillman JR. Value assessment of evolving pediatric appendicitis imaging strategies between 2004 and 2018. Journal of the American College of Radiology. 2020 Dec 1;17(12):1549-54.

[15] Zhang Y, Xia H, Wang Y, Chen L, Li S, Hussein IA, Wu Y, Shang Y, Yao S, Du R. The rate of missed diagnosis of lower-limb DVT by ultrasound amounts to 50% or so in patients without symptoms of DVT: A meta-analysis. Medicine. 2019 Sep 1;98(37):e17103.

[16] Audu CO, Wakefield TW, Coleman DM. Pediatric deep venous thrombosis. Journal of Vascular Surgery: Venous and Lymphatic Disorders. 2019 May 1;7(3):452-62.

[17] Roberts JR, Hedges JR. Roberts and Hedges' clinical procedures in emergency medicine E-book. Elsevier Health Sciences; 2013 May 28.

[18] Kim HC, Kim SW, Won KY. Groin abnormalities: ultrasonographic and clinical findings. Ultrasonography. 2020 Apr;39(2):166.

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