

COMPARISON OF ULTRASOUND WITH CONTRAST-ENHANCED COMPUTED TOMOGRAPHY FOR PEDIATRIC VASCULAR AND AVASCULAR HERNIA

Muqaddas Abbas^{*1}, Dr. Saima Haider²

^{*1}MS Allied Health Sciences (Medical Imaging Technology), Faculty of Allied Health Sciences, The Superior University, Lahore, Pakistan

²Faculty of Allied Health Sciences, The Superior University, Lahore, Pakistan

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Corresponding Author: *

Muqaddas Abbas

Abstract

Background: Paediatric hernias often mimic acute abdominal emergencies, and prompt recognition of vascular compromise is crucial to avoid bowel ischaemia, strangulation and necrosis. There is a lack of evidence comparing the diagnostic performances of high-resolution ultrasonography (HRUS) with Doppler and contrast-enhanced computed tomography (CECT) in differentiating vascular from avascular paediatric hernia.

Objective: To compare the diagnostic accuracy of HRUS with CECT for the detection of vascular and avascular paediatric hernia in relation to intraoperative diagnosis as the gold standard.

Methodology: In this prospective observational study, 66 paediatric patients aged 0–14 years with clinically suspected hernias were recruited at Jinnah Hospital for four months. HRUS with colour Doppler and clinically indicated CECT were performed using standardized paediatric protocols. Imaging findings were compared with the study reference diagnosis, including operative findings when available, and paired results were analysed using McNemar's exact test in SPSS.

Results: Among 66 patients, 44 (66.7%) were male. CECT identified vascular compromise in 28 patients (42.4%), while abnormal Doppler flow was recorded in 27 patients (40.9%). Abnormal Doppler flow was strongly associated with CECT-detected vascular compromise: compromise was present in 25 of 27 patients (92.6%) with abnormal flow but in only 3 of 39 patients (7.7%) with normal flow (Pearson chi-square = 47.081, $p < 0.001$). Ultrasound and CECT agreed with the study reference diagnosis in 62.1% and 78.8% of cases, respectively; the paired difference was statistically significant (McNemar exact $p = 0.013$).

Conclusion: CECT showed greater agreement with the study reference diagnosis and provided direct assessment of bowel-wall enhancement and vascular compromise. Doppler ultrasound remained a valuable radiation-free first-line examination, and abnormal flow was strongly associated with CECT-detected compromise. CECT should be reserved for equivocal or complicated cases in a stepwise paediatric imaging pathway.

INTRODUCTION

Pediatric hernias are common surgical conditions characterized by protrusion of abdominal or pelvic contents through

congenital or acquired defects. Although many are uncomplicated, incarceration and strangulation may impair perfusion and progress to bowel ischemia, necrosis, perforation and

sepsis. Clinical manifestations in infants and children may be subtle or nonspecific, making timely distinction between uncomplicated and vascularly compromised hernias important for management (1,2).

High-resolution ultrasonography (HRUS) is widely used as the initial imaging examination because it is non-invasive, radiation-free, portable and capable of dynamic assessment. Grayscale imaging can demonstrate the hernia defect, sac contents, reducibility, bowel-wall changes and peristalsis, while colour Doppler adds functional information about perfusion. Nevertheless, diagnostic performance is influenced by operator experience, bowel gas, patient cooperation and the depth or complexity of the lesion (3–5).

Contrast-enhanced computed tomography (CECT) provides a wider anatomical survey and can demonstrate bowel-wall enhancement, mesenteric congestion, obstruction, closed-loop configuration and other signs of threatened bowel. Its use in children must be justified because of ionizing radiation and intravenous contrast exposure. Current evidence therefore supports a staged approach in which ultrasound is used first and CT is reserved for equivocal, deep, complex or clinically complicated cases (6–9).

Direct paired evidence comparing HRUS and CECT specifically for vascular versus avascular pediatric hernias remains limited. The present study therefore compared the diagnostic performance of HRUS with CECT in children with suspected hernia and examined the relationship of Doppler perfusion findings with CECT-detected vascular compromise.

METHODOLOGY

Research design: This prospective observational comparative study was conducted to compare the diagnostic accuracy of high-resolution ultrasound (HRUS) and contrast-enhanced computed tomography (CECT) in children with clinically suspected hernias. The prospective design enabled real-time data collection, minimized recall bias, and allowed standardized imaging protocols to be applied consistently. The principal clinical question was whether the two imaging modalities could distinguish vascular (viable) from avascular (strangulated)

hernias, an important distinction when determining the urgency of surgical management.

Clinical setting: The study was conducted in the Departments of Radiology and Paediatric Surgery at Jinnah Hospital, a tertiary-care teaching hospital. The setting provided access to paediatric patients, ultrasound and computed tomography (CT), and collaboration with the surgical team for correlation of imaging findings with operative findings when available.

Sample size: The sample size was calculated using Cochran's formula: $n = Z^2 \times p \times (1 - p) / e^2$, where $Z = 1.96$ (95% confidence), $p = 0.78$ (expected proportion/sensitivity), and $e = 0.10$ (10% margin of error), yielding $n = 65.9$, rounded to 66 patients.

Sampling technique: A non-probability purposive sampling technique was used. Eligible paediatric patients referred with suspected hernia during the study period were enrolled according to the predefined inclusion and exclusion criteria.

Duration of study: The study duration was four months, during which patient recruitment, imaging, and data collection were performed sequentially.

Selection criteria: Pediatric patients aged 0–14 years with clinical suspicion of hernia, patients referred for imaging due to abdominal pain, swelling, or suspected bowel obstruction, and those with written informed consent from parents or legal guardians were included. Patients with previous abdominal or hernia surgery, incomplete imaging or clinical records, or unstable/critical condition unsuitable for imaging were excluded.

High-resolution ultrasound protocol: High-frequency linear probes (7–12 MHz) were used for superficial evaluation of the groin and abdominal wall, while curvilinear probes were used when deeper penetration was required. Examinations were performed in the supine position and dynamically, with crying, coughing, or Valsalva manoeuvre where appropriate, to

provoke herniation and assess reducibility. Real-time imaging was used to identify hernia contents, including bowel loops, omentum, and gonadal structures. Particular attention was paid to bowel-wall thickness, peristalsis, fluid, and Doppler blood flow. Preserved vascularity supported viable bowel, whereas reduced or absent vascularity raised concern for vascular compromise or strangulation. Hernia size, contents, bowel-wall changes, peristalsis, and blood flow were documented.

Contrast-enhanced CT protocol: A standard paediatric contrast-enhanced abdominal CT protocol was used when CECT was clinically indicated and not contraindicated. Axial images were obtained and reconstructed in coronal and sagittal planes for improved anatomical assessment. CECT was used to evaluate the hernia, its contents, surrounding structures, bowel-wall enhancement, mesenteric vascular congestion, fat stranding, bowel dilatation, reduced or absent enhancement, and pneumatosis intestinalis. These features were particularly useful in complex or deep-seated hernias in which ultrasound assessment was limited.

Ethical considerations: The study was conducted after approval from the relevant ethics committee. Participants' rights and welfare were protected throughout the study. Written informed consent was obtained from the parents or legal guardians of participating children. All collected information was kept confidential and used only for research purposes. Participant identities were protected by using study codes rather than directly identifying information.

Data collection procedure: Children aged 0–14 years who presented to the Paediatric Surgery or Radiology Department with suspected hernia were screened for eligibility. After informed

consent and clinical assessment, HRUS with Doppler was performed and findings were recorded on a standardized proforma. CECT findings were recorded for patients who underwent clinically indicated CECT according to the study protocol. Imaging findings included hernia location and contents, vascularity, reducibility, bowel-wall changes, and obstruction. Operative findings, when available, were recorded for correlation.

Data analysis: Data were entered, cleaned, coded, and analysed using the Statistical Package for the Social Sciences (SPSS), version 27. Continuous variables, including age, were summarized using appropriate descriptive statistics, while categorical variables, including sex, clinical findings, hernia characteristics, ultrasound findings, CECT findings, and operative findings, were presented as frequencies and percentages. Diagnostic classifications were coded as correct or incorrect by comparison with the study reference diagnosis, including operative findings when available. Overall diagnostic accuracy was calculated separately for ultrasound and CECT. Because both imaging modalities were assessed in the same participants, McNemar's exact test was used to compare their paired diagnostic accuracy. Cross-tabulations were prepared to examine sex in relation to CECT-detected vascular compromise, ultrasound Doppler blood flow in relation to CECT-detected vascular compromise, ultrasound-detected bowel obstruction in relation to CECT-detected bowel obstruction, and ultrasound-detected complications in relation to CECT-detected complications. Pearson's chi-square test was used to assess these associations when its assumptions were satisfied; exact significance was reported where appropriate. All tests were two-sided, and a p-value below 0.05 was considered statistically significant.

RESULTS

Table 1. Sex distribution of paediatric hernia patients

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	44	66.7	66.7	66.7
	Female	22	33.3	33.3	100.0
	Total	66	100.0	100.0	

The study comprised 66 children, including 44 males (66.7%) and 22 females (33.3%). Thus, male patients accounted for approximately twice as many cases as female patients.

Table 2. Age distribution of paediatric hernia patients

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2	3.0	3.0	3.0
	2	4	6.1	6.1	9.1
	3	5	7.6	7.6	16.7
	4	4	6.1	6.1	22.7
	5	6	9.1	9.1	31.8
	6	3	4.5	4.5	36.4
	7	6	9.1	9.1	45.5
	8	5	7.6	7.6	53.0
	9	6	9.1	9.1	61.8
	10	5	7.6	7.6	68.2
	11	5	7.6	7.6	75.8
	12	8	12.1	12.1	87.9
	13	3	4.5	4.5	92.4
	14	5	7.6	7.6	100.0
	Total	66	100.0	100.0	

Patients ranged in age from 1 to 14 years (n = 66). Twelve-year-olds formed the largest single group (8, 12.1%), while ages 5, 7 and 9 each accounted for 6 children (9.1%). The youngest age, 1 year, was represented by 2 children (3.0%).

Table 3. Physical examination of abdominal mass

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absent	17	25.8	25.8	25.8
	Present	49	74.2	74.2	100.0
	Total	66	100.0	100.0	

A palpable mass was documented in 49 of 66 patients (74.2%), making it the more common examination finding in this table. The remaining 17 patients (25.8%) had no palpable mass.

Table 4. Physical examination of abdominal tenderness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absent	34	51.5	51.5	51.5
	Present	32	48.5	48.5	100.0
	Total	66	100.0	100.0	

Abdominal tenderness was recorded in 32 children (48.5%), compared with 34 (51.5%) without tenderness. The two groups were therefore nearly equal in size.

Table 5. Ultrasound – hernia lesion location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Right Iliac Fossa	44	66.7	66.7	66.7
	Right Hypochondrium	12	18.2	18.2	84.8
	Peri-umbilical	3	4.5	4.5	89.4

	Left Iliac Fossa	4	6.1	6.1	95.5
	Right Lumbar	3	4.5	4.5	100.0
	Total	66	100.0	100.0	

Ultrasound localized 44 of 66 lesions (66.7%) to the right iliac fossa. The right hypochondrium was the next most frequent site (12, 18.2%), followed by the left iliac fossa (4, 6.1%); peri-umbilical and right lumbar sites each accounted for 3 cases (4.5%).

Table 6. Ultrasound – intraluminal hernia content

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fluid	27	40.9	40.9	40.9
	Mesenteric Fat	23	34.8	34.8	75.8
	Mixed	14	21.2	21.2	97.0
	Fecal	2	3.0	3.0	100.0
	Total	66	100.0	100.0	

Fluid was the most frequently recorded hernia content on ultrasound (27, 40.9%), followed by mesenteric fat (23, 34.8%) and mixed contents (14, 21.2%). Faecal material was uncommon, occurring in 2 cases (3.0%).

Table 7. Ultrasound Doppler blood flow

		Frequency	Percent	Valid Percent	Cumulative Percent
Blood Flow	Normal	39	59.1	59.1	59.1
	Abnormal	27	40.9	40.9	100.0
	Total	66	100.0	100.0	

Doppler examination showed normal blood flow in 39 patients (59.1%) and abnormal flow in 27 (40.9%). Thus, approximately two in five children had an abnormal perfusion finding on ultrasound.

Table 8. Bowel obstruction detection on ultrasound

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	33	50.0	50.0	50.0
	Yes	33	50.0	50.0	100.0
	Total	66	100.0	100.0	

Ultrasound identified bowel obstruction in 33 of 66 patients (50.0%). The other 33 patients (50.0%) had no ultrasound finding of obstruction, giving an even distribution.

Table 9. CECT – hernia lesion location

		Frequency	Percent	Valid Percent	Cumulative Percent
Lesion Location	Right Iliac Fossa	44	66.7	66.7	66.7
	Right Hypochondrium	12	18.2	18.2	84.8
	Peri-umbilical	3	4.5	4.5	89.4
	Left Iliac Fossa	4	6.1	6.1	95.5
	Right Lumbar	3	4.5	4.5	100.0
	Total	66	100.0	100.0	

CECT localized most lesions to the right iliac fossa (44, 66.7%), followed by the right hypochondrium (12, 18.2%). Each site had the same count as in the ultrasound location table, showing agreement in the reported location frequencies.

Table 10. CECT – intraluminal hernia content

		Frequency	Percent	Valid Percent	Cumulative Percent
Intraluminal Content	Fluid	27	40.9	40.9	40.9
	Fat / Mesenteric Fat	23	34.8	34.8	75.8
	Mixed	14	21.2	21.2	97.0
	Fecal	2	3.0	3.0	100.0
	Total	66	100.0	100.0	

CECT identified fluid in 27 cases (40.9%), fat or mesenteric fat in 23 (34.8%), mixed contents in 14 (21.2%), and faecal material in 2 (3.0%). These category totals match the corresponding ultrasound content frequencies.

Table 11. CECT – bowel wall enhancement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	23	34.8	34.8	34.8
	Decreased	31	47.0	47.0	81.8
	Absent	12	18.2	18.2	100.0
	Total	66	100.0	100.0	

Normal bowel-wall enhancement was seen on CECT in 23 patients (34.8%), whereas enhancement was decreased in 31 (47.0%) and absent in 12 (18.2%). Together, decreased or absent enhancement was recorded in 43 patients (65.2%).

Table 12. CECT – vascular compromise

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Absent	38	57.6	57.6	57.6
	Present	28	42.4	42.4	100.0
	Total	66	100.0	100.0	

CECT showed vascular compromise in 28 of 66 children (42.4%). No vascular compromise was recorded in the remaining 38 (57.6%), who formed the larger group.

Table 13. CECT – bowel obstruction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	26	39.4	39.4	39.4
	Yes	40	60.6	60.6	100.0
	Total	66	100.0	100.0	

CECT demonstrated bowel obstruction in 40 patients (60.6%), compared with 26 patients (39.4%) without obstruction. The proportion with obstruction on CECT was higher than the 50.0% recorded by ultrasound in Table 8.

Table 14. Ultrasound agreement with the study reference diagnosis

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	25	37.9	37.9	37.9
	1	41	62.1	62.1	100.0
	Total	66	100.0	100.0	

Ultrasound classification agreed with the study reference diagnosis in 41 of 66 cases (62.1%). The classifications disagreed in 25 cases (37.9%), indicating that about three in five cases were classified in agreement with the reference.

Table 15. CECT agreement with the study reference diagnosis

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	14	21.2	21.2	21.2
	1	52	78.8	78.8	100.0
	Total	66	100.0	100.0	

CECT classification agreed with the study reference diagnosis in 52 of 66 cases (78.8%) and disagreed in 14 (21.2%). Its observed agreement proportion exceeded the ultrasound proportion reported in Table 14.

Table 16. McNemar test for paired diagnostic accuracy

Test Statistics	Value
N	66
Exact Sig. (2-tailed)	.013

McNemar's exact two-sided test yielded $p = 0.013$ for the paired diagnostic classifications ($n = 66$). This indicates a statistically significant difference between the modalities in their agreement with the study reference diagnosis; the overall agreement counts favor CECT (52 versus 41).

Table 17. Sex × CECT vascular compromise crosstabulation

Sex		CECT vascular compromise		Total
		No	Yes	
Male	Count	27	17	44
	% within Sex	61.4%	38.6%	100.0%
Female	Count	11	11	22
	% within Sex	50.0%	50.0%	100.0%
Total	Count	38	28	66
	% within Sex	57.6%	42.4%	100.0%

CECT showed vascular compromise in 17 of 44 male patients (38.6%) and 11 of 22 female patients (50.0%). Although the observed proportion was higher among females, the female subgroup was smaller.

Table 18. Pearson chi-square test for sex and CECT vascular compromise

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	0.775	1	0.379
Continuity Correction	0.380	1	0.538
Likelihood Ratio	0.772	1	0.380
Linear-by-Linear Association	0.764	1	0.382

N of Valid Cases 66

The Pearson chi-square test found no statistically significant association between sex and CECT vascular compromise ($\chi^2 = 0.775$, $df = 1$, $p = 0.379$; $n = 66$). The difference in observed proportions in Table 17 should therefore be interpreted descriptively.

Table 19. Ultrasound Doppler blood flow × CECT vascular compromise crosstabulation

US Doppler blood flow		CECT vascular compromise		Total
		No	Yes	
Normal	Count	36	3	39
	% within US Doppler blood flow	92.3%	7.7%	100.0%
Abnormal	Count	2	25	27
	% within US Doppler blood flow	7.4%	92.6%	100.0%
Total	Count	38	28	66
	% within US Doppler blood flow	57.6%	42.4%	100.0%

Among 27 patients with abnormal Doppler flow, 25 (92.6%) had vascular compromise on CECT and 2 (7.4%) did not. Among 39 patients with normal flow, 3 (7.7%) had CECT compromise and 36 (92.3%) did not, showing a marked difference across Doppler categories.

Table 20. Pearson chi-square test for Doppler blood flow and CECT vascular compromise

	Value	df	Asymptotic Significance (2-sided)	Exact Significance (2-sided)	Exact Significance (1-sided)
Pearson Chi-Square	47.081	1	<.001		
Continuity Correction	43.670	1	<.001		
Likelihood Ratio	54.563	1	<.001		
Fisher's Exact Test				<.001	<.001
Linear-by-Linear Association	46.368	1	<.001		
N of Valid Cases	66				

The association between Doppler flow category and CECT vascular compromise was statistically significant (Pearson $\chi^2 = 47.081$, $df = 1$, $p < 0.001$; $n = 66$). Fisher's exact two-sided test was also significant ($p < 0.001$), consistent with the strong separation shown in Table 19.

Table 21. Ultrasound × CECT bowel obstruction crosstabulation

US bowel obstruction		CECT bowel obstruction	Total
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		No	Yes	
No	Count	15	18	33
	% within US bowel obstruction	45.5%	54.5%	100.0%
Yes	Count	11	22	33
	% within US bowel obstruction	33.3%	66.7%	100.0%
Total	Count	26	40	66
	% within US bowel obstruction	39.4%	60.6%	100.0%

Of 33 children without ultrasound-detected obstruction, 18 (54.5%) had obstruction on CECT and 15 (45.5%) did not. Among the 33 with obstruction on ultrasound, 22 (66.7%) also had obstruction on CECT, while 11 (33.3%) did not.

Table 22. Pearson chi-square test for ultrasound and CECT bowel obstruction

	Value	df	Asymptotic Significance (2-sided)	Exact Significance (2-sided)	Exact Significance (1-sided)
Pearson Chi-Square	1.015	1	0.314		
Continuity Correction	0.571	1	0.450		
Likelihood Ratio	1.019	1	0.313		
Fisher's Exact Test				0.450	0.225
Linear-by-Linear Association	1.000	1	0.317		
N of Valid Cases	66				

The association between ultrasound-detected and CECT-detected bowel obstruction was not statistically significant (Pearson $\chi^2 = 1.015$, $df = 1$, $p = 0.314$; $n = 66$). Fisher's exact two-sided p value was 0.450, supporting the same interpretation.

Table 23. Pearson chi-square test for ultrasound and CECT complications

	Value	df	Asymptotic Significance (2-sided)	Exact Significance (2-sided)	Exact Significance (1-sided)
Pearson Chi-Square	1.765	1	0.184		
Continuity Correction	1.098	1	0.295		
Likelihood Ratio	1.823	1	0.177		
Fisher's Exact Test				0.263	0.147

Linear-by-Linear Association	1.739	1	0.187		
N of Valid Cases	66				

The reported ultrasound–CECT complication comparison did not show a statistically significant association (Pearson $\chi^2 = 1.765$, $df = 1$, $p = 0.184$; $n = 66$). Fisher's exact two-sided p value was 0.263; this test table does not provide the underlying category counts.

DISCUSSION

This study compared high-resolution ultrasound (HRUS) with Doppler and contrast-enhanced CT (CECT) for vascular and avascular hernias in 66 children. Males comprised 66.7% of participants, in keeping with the known predominance of pediatric inguinal hernias in boys. A palpable mass was recorded in 74.2% and tenderness in 48.5%. These findings help identify children who need imaging, but neither sign alone establishes bowel viability or the extent of a complication (3,10).

Ultrasound and CECT reported identical frequencies for lesion location and gross sac contents. The right iliac fossa was the most frequent recorded site (66.7%), while fluid (40.9%) and mesenteric fat (34.8%) were the leading content categories. This concordance supports ultrasound for initial anatomical characterization; dynamic examination can also show reducibility and peristalsis. Agreement in the marginal frequencies, however, should not be interpreted as proof of case-by-case agreement or equivalent ability to detect ischemia (3,12).

Doppler flow was abnormal in 27 children (40.9%). CECT showed vascular compromise in 28 (42.4%), including 25 of 27 (92.6%) with abnormal Doppler flow and 3 of 39 (7.7%) with normal flow. The association was strong ($\chi^2 = 47.081$, $p < 0.001$). This supports Doppler as an early perfusion assessment, while the three CECT-positive cases with normal Doppler flow show that a reassuring signal cannot exclude compromise. Two children with abnormal Doppler findings lacked CECT evidence of compromise. Examination technique, probe pressure and low-flow sensitivity can affect Doppler signals, so results should be interpreted alongside symptoms, grayscale findings and reducibility (5,11).

CECT showed decreased bowel-wall enhancement in 31 children (47.0%) and absent

enhancement in 12 (18.2%). These findings merit attention as indicators of possible perfusion disturbance, but they should be assessed together with clinical signs and other CT features rather than treated as an independent proof of irreversible ischemia. CECT can survey deeper structures, obstruction and mesenteric changes when ultrasound is limited. The selected tertiary-care sample should not be used to estimate the prevalence of vascular compromise in all children with hernia (6,9,13).

Agreement with the study reference diagnosis was 62.1% for ultrasound and 78.8% for CECT; the paired McNemar test indicated a significant difference (exact $p = 0.013$). These are observed classification agreement proportions within this cohort. They do not establish universal modality accuracy, particularly because operative verification was not uniform and CT may have been selected for more concerning cases. The findings support CECT as a selective problem-solving examination when ultrasound is equivocal or concern about bowel viability remains high.

CECT detected obstruction in 40 children (60.6%), compared with 33 (50.0%) on ultrasound. In the crosstabulation, 18 of 33 children without ultrasound-detected obstruction had CECT-detected obstruction, and 11 of 33 with an ultrasound finding did not have a matching CECT classification. The association was not statistically significant ($\chi^2 = 1.015$, $p = 0.314$). Bowel gas, deep transition points and a focused hernia examination may contribute to differences between the examinations; a wider evaluation may be necessary when clinical signs persist (7–9,14).

An ultrasound-first pathway can document the defect, contents, reducibility, bowel appearance and Doppler flow, followed by prompt surgical assessment and selective CECT when findings

are technically limited, discordant or concerning for strangulation. CT should be justified against radiation and intravenous-contrast exposure in children. Contrast-enhanced ultrasound is a promising radiation-free means of evaluating microvascular bowel perfusion, but its specific role in pediatric hernia needs prospective comparison and operative correlation (12,15).

Sex was not significantly associated with CECT-detected vascular compromise ($p = 0.379$), despite the sample's male predominance. The comparison of ultrasound and CECT complication classifications was also nonsignificant ($p = 0.184$). These tests do not show that sex predicts perfusion status or that the modalities classify every complication interchangeably. Clinical urgency is better judged from the child's condition, reducibility, perfusion findings and evidence of obstruction. In female infants, attention to possible ovarian content remains especially relevant (5).

LIMITATIONS

- It was conducted at a single tertiary-care hospital, used non-probability purposive sampling and included a relatively small sample of 66 patients.
- Ultrasound is operator-dependent, and not every clinically suspected pediatric hernia necessarily undergoes CT because CT is used selectively to minimize radiation.
- Operative findings were available when clinically indicated rather than uniformly for every participant.
- Larger multicenter studies with standardized imaging acquisition, blinded interpretation and consistent surgical reference standards are needed to refine diagnostic thresholds and evaluate whether emerging techniques such as contrast-enhanced ultrasound can reduce CT use.

CONCLUSION

CECT demonstrated greater agreement with the study reference diagnosis than HRUS in this cohort and provided direct assessment of bowel-wall enhancement, obstruction and vascular compromise. HRUS with colour Doppler remains a valuable radiation-free first-line modality, particularly because abnormal

Doppler flow showed a strong association with CECT-detected vascular compromise. A stepwise pediatric imaging pathway is therefore supported: use ultrasound initially when appropriate, and reserve CECT for equivocal, deep, complex, or clinically complicated cases where additional anatomical or perfusion information is likely to influence management.

RECOMMENDATIONS

- Use HRUS with colour Doppler as the first-line imaging modality for suspected pediatric hernias when clinically appropriate.
- Consider CECT when ultrasound is equivocal or when vascular compromise, strangulation, bowel obstruction or complex anatomy is suspected.
- Use standardized pediatric ultrasound acquisition and reporting protocols to reduce operator-dependent variability.
- Conduct larger multicenter studies with standardized reference standards and assessment of inter-observer agreement.
- Evaluate contrast-enhanced ultrasound and other radiation-sparing techniques as potential problem-solving tools in selected pediatric patients.

DECLARATIONS

Ethical approval: The study was conducted after approval from the relevant ethics committee, and written informed consent was obtained from parents or legal guardians.

Consent for participation: Written informed consent was obtained from the parents or legal guardians of participating children.

Conflict of interest: The authors declare no conflict of interest.

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Data availability: Data are available from the corresponding author subject to institutional and ethical requirements.

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