



# Enlargement of the Pancreas in Children Diagnosed with Acute Pancreatitis: An Approach Based on P/V Ratio

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## Abstract

**Background** Acute pancreatitis is a reversible inflammation of the pancreatic parenchyma. Enlargement of the pancreas is often envisaged in such conditions. This study evaluates P/V ratio, as a marker to decide pancreatic enlargement in disease condition.

**Purpose** The aim of this study was to develop imaging-based diagnostic criterion for acute pancreatitis in children based on P/V ratio.

**Material and Methods** This study included 37 children with acute pancreatitis and 283 children asymptomatic for pancreatic disorders, from a single hospital center. The age of children ranged between 2 and 18 years. P/V ratio, which is the ratio of greatest anteroposterior dimension of the head, body, and tail of the pancreas relative to the transverse lumbar vertebral body, was obtained for each child through ultrasonographic examination. Age-adjusted receiver operating characteristics (AROC) analysis was performed on P/V ratio at presentation for each pancreatic region, and the sensitivity at 90% specificity, the threshold errors, and the corresponding cutoffs were obtained. The enlargement assessment was also done after clinical recovery by referring to the cutoffs of respective regions.

**Results** AROC analysis for males and females resulted into a maximum sensitivity of 83.33 and 81.67%, respectively, at 90% specificity for head. The error thresholds for both the groups were same, i.e., 0.098, indicating that 90% of the observations had errors less than the threshold. The corresponding P/V ratio cutoff for males and females was 0.43 and 0.42, respectively.

**Conclusion** Radiologists and clinicians can refer a cutoff value of 0.4 for each region, along with hypoechogenicity, to decide about enlargement of the pancreas in acute pancreatitis condition.

## Keywords

- ▶ acute pancreatitis
- ▶ acute recurrent pancreatitis
- ▶ age-adjusted receiver operating characteristics
- ▶ anteroposterior

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## Introduction

Acute pancreatitis (AP) is a disease in which there is an autolysis of this organ.<sup>1</sup> It is increasingly being recognized as a clinical entity in childhood.<sup>2</sup> Pediatric onset of AP is labeled when the first episode of AP occurs before the patient's 19th birthday.<sup>3</sup> AP is the most common pancreatic disorder in children.<sup>4</sup> Pancreatitis can be local or diffuse,<sup>5</sup> and the incidence is 3 to 13 episodes per year.<sup>1</sup>

The INSPPIRE (INternational Study Group of Pediatric Pancreatitis: In Search for a CuRE) consortium meeting in December 2010 and May 2011 operationally defined the diagnosis of AP as requiring two of the following three criteria: (1) abdominal pain compatible with AP, (2) serum amylase or lipase levels greater or equal to three times the upper limits of normal, and (3) imaging findings consistent with AP.<sup>1,3,6</sup> As per the first INSPPIRE criterion, acute onset of persistent upper abdominal pain along with nausea and vomiting is the hallmark symptom of AP.<sup>7</sup> In various reported studies of AP, 80 to 95% of patients have presented with abdominal pain. The most common location of the pain is epigastric region (62–89%). In nonverbal children, irritability was a common presenting complaint and may be a surrogate for complaints of pain in this age group.<sup>8</sup> Measurements of serum lipase had a sensitivity and specificity of 96.6 and 99.4%, respectively, whereas serum amylase had a sensitivity and specificity of 78.6 and 99.1%, respectively. Thus, it is not uncommon to have normal serum amylase in 20% of patients with AP.<sup>9</sup>

Currently, ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) are the three most used imaging modalities for evaluating pancreatitis in pediatric population.<sup>10</sup> Abdominal ultrasonography (USG) is used as the radiologic procedure of choice in examination of children with symptoms referable to the pancreas,<sup>2,3,6–8,11</sup> and it has shown 80% accuracy in the evaluation of pancreatitis.<sup>8,12</sup>

The utility of sonography in pediatric patient is more, as it can be performed at the patient's bed side and with cheap instrument, lack of invasion, no radiation, repetitive character, and no need of sedation. Nearly, 20% or more of children with AP initially have normal imaging finding, especially in early or mild cases,<sup>10</sup> and the sensitivity of transabdominal US in detecting pancreatitis was reported as 79.4%.<sup>10,13</sup> USG findings in AP often result in hypoechoic gland that is focally or diffusely enlarged.<sup>5,6,14,15</sup> P/V ratio, which is the ratio of greatest anteroposterior dimension of the body of the pancreas relative to the transverse lumbar vertebral, when associated with a hypoechoic pancreatic parenchyma, is indicative of AP.<sup>16</sup> The P/V ratio remains consistent with age in normal children but changes on higher side in AP patients because of diffuse or focal enlargement of the pancreas in AP.

Referring to the imaging criterion of INSPPIRE consortium, as on date, there are no specific guidelines to decide the enlargement of the pancreas in AP. Therefore, this study aims at using P/V ratio to determine the extent of enlargement of head, body, and tail of the pancreas in AP cases. Till date, no

study has focused on using P/V ratio for enlargement of all the three parts in AP.

## Materials and Methods

In this diagnostic evaluation study, we reviewed and analyzed the medical records of 44 children with AP, admitted to a children hospital center with attached radiology unit, from Nagpur, Maharashtra. The age of children ranged from 2.9 to 16.9 years as reported during the period from September 2007 to December 2019. The complete demographic, clinical, biochemical, and radiological details were retrieved from medical records for these children. From records, it was observed that: (1) all these patients presented with severe epigastric abdominal pain lasting more than 48 hours with persistent vomiting and (2) serum amylase level was more than three times the upper limit of normal, i.e., more than 375 IU by kinetic method (normal: 25–125 IU by kinetic method). Hence, based on these two criteria, the diagnosis of AP was made according to the INSPPIRE criteria. To establish the imaging-based criterion for enlargement of the pancreas in AP and in the absence of normative data on pancreatic dimensions, a study was conducted during June 2016 to December 2019 in which normal children were enrolled for abdominal USG evaluation for P/V ratio. The aim was to establish the age- and gender-specific pancreatic dimensions in normal children, so as to ascertain pancreatic enlargement in the disease condition. Till December 2019, a total of 283 children in the age range of 2 months till 18 years were consecutively enrolled in the study upon fulfillment of inclusion and exclusion criteria and proper consent from accompanying parent. These controls were not part of the data from other study. Anthropometric measurements were available for all the individuals in both the groups. The GoldTech instrument from Precision Electronic Instruments Company, New Delhi, was used for weighing infants, whereas older children were measured using instrument by Detecto Medical Scales Inc., United States. Weights were recorded to the nearest 100 g. The supine lengths were measured on an infant meter in children below 2 years and standing height was measured on stadiometer in children above 2 years to the nearest 1 mm. As regards inclusion criteria, in the control group, (1) normal healthy siblings of patients attending outpatient department and those visiting for vaccination and (2) those children without any clinical or laboratory evidence of pancreatic disorder were included. Further, patients having chronic pancreatitis, acute on chronic pancreatitis and biliary diseases,<sup>4,16</sup> clinical and laboratory evidence of hepatic diseases,<sup>17,18</sup> diabetic ketoacidosis,<sup>4</sup> renal insufficiency,<sup>4</sup> acute appendicitis,<sup>4</sup> acute intestinal obstruction,<sup>4</sup> and cystic fibrosis<sup>17,19</sup> and having vertebral column deformity were excluded from the study. All included patients with AP received medical treatment and were followed up for the entire hospital course till clinical recovery. Once the clinical recovery was achieved, these patients were subjected to a second abdominal USG. A total of 44 AP patients were documented from medical

records, but of these only 37 patients qualified for P/V ratio estimation as the sonograms of these patients had technically adequate pancreatic dimensions (according to the anatomical landmarks for head, body, and tail), echogenicity, and lumbar vertebral body width for measurement of middle transverse diameter. Therefore, data on these 37 patients with AP were considered for analysis. The Institutional Ethics Committee approved the study protocol (Ref: NKPSIMS & RC and LMH/Pharmacology/7/2020 dated: January 31, 2020).

### Abdominal Ultrasonography

SonoAce X8 Medison Korean (SAX8), a duly calibrated machine with 3.5-, 5-, and 7.5-MHz sector electronic probes, was used, and all these 44 patients and the control group were studied on this machine from September 2007 till December 2019. The radiologist performing the USG remained same throughout this study for the AP and control group, and he was blinded to the clinical parameters for healthy control examinations. The pancreatic measurements were performed at the time of US examination.

### Anatomical Landmarks for Head, Body, and Tail of the Pancreas and Lumbar Vertebral Body

- **Pancreatic head:** For measuring the head of the pancreas, the duodenum, which envelops the lateral and caudal contour of the head, was taken as a landmark for measurements,<sup>17,20</sup> where the pancreatic head was usually directly ventral to the inferior vena cava.<sup>21</sup>
- **Pancreatic body:** The superior mesenteric artery and splenic vein served as an important landmark for localization of the body of the pancreas.<sup>17,20</sup> Compression scanning with a “large footprint” curved linear transducer was the key technique in visualizing the body of the pancreas.<sup>21</sup>
- **Pancreatic tail:** The splenic artery and vein facilitated identification of tail of the pancreas with the scanning through the spleen and left kidney, as the tail was opposite to the medial margin of left kidney.<sup>17,21</sup>
- **Lumbar vertebral:** The body was localized by using a transverse probe, and the width of the pancreatic body was assessed at the level of the splenic vein. Then, the width of lumbar vertebral body was delineated, as the body of the pancreas lies on the posterior abdominal wall behind the stomach at the level of first and second lumbar vertebrae.<sup>17,22,23</sup> Sample sonograms are shown in ►Fig. 1A–C for three patients at presentation and after clinical recovery.

The sonographic examination of the pancreas involved assessment of the greatest anteroposterior dimension of the head, body, and tail regions, as well as the overall texture, when compared with that of the liver at a similar depth. The diameter of the head, body, and tail was measured perpendicular to the long axis of the organ. The maximum anteroposterior diameters of the head, body, and tail of the pancreas were measured on transverse/oblique images. If the pancreas was oriented transversely across the abdomen,

then the entire gland could be seen in one image. However, the pancreas often had varying degree of obliquity, with the tail lying more cranial than the head and body. In these cases, several images were necessary to demonstrate the entire gland.<sup>17</sup> Pancreatic echogenicity was determined by comparison with the adjacent liver at a similar depth on both transverse and longitudinal views. Pancreatic echogenicity was categorized as less than, equal to, or greater than liver echogenicity.<sup>17,19</sup> The measurement for vertebral body was taken at middle vertebral body width of lumbar vertebra, which measures transverse diameter of the vertebral body in the same scan.<sup>22</sup> The sonographic examination was mostly conducted in the morning hours with the patient in fasting state and in supine position to eliminate the difference of dimensions in different positions. Some children are required to drink nearly 200 to 400 mL of water to delineate the image of the pancreas, which could have been obscured by the gas in the stomach. No other pretreatment was used.<sup>16,18</sup>

### Statistical Methods

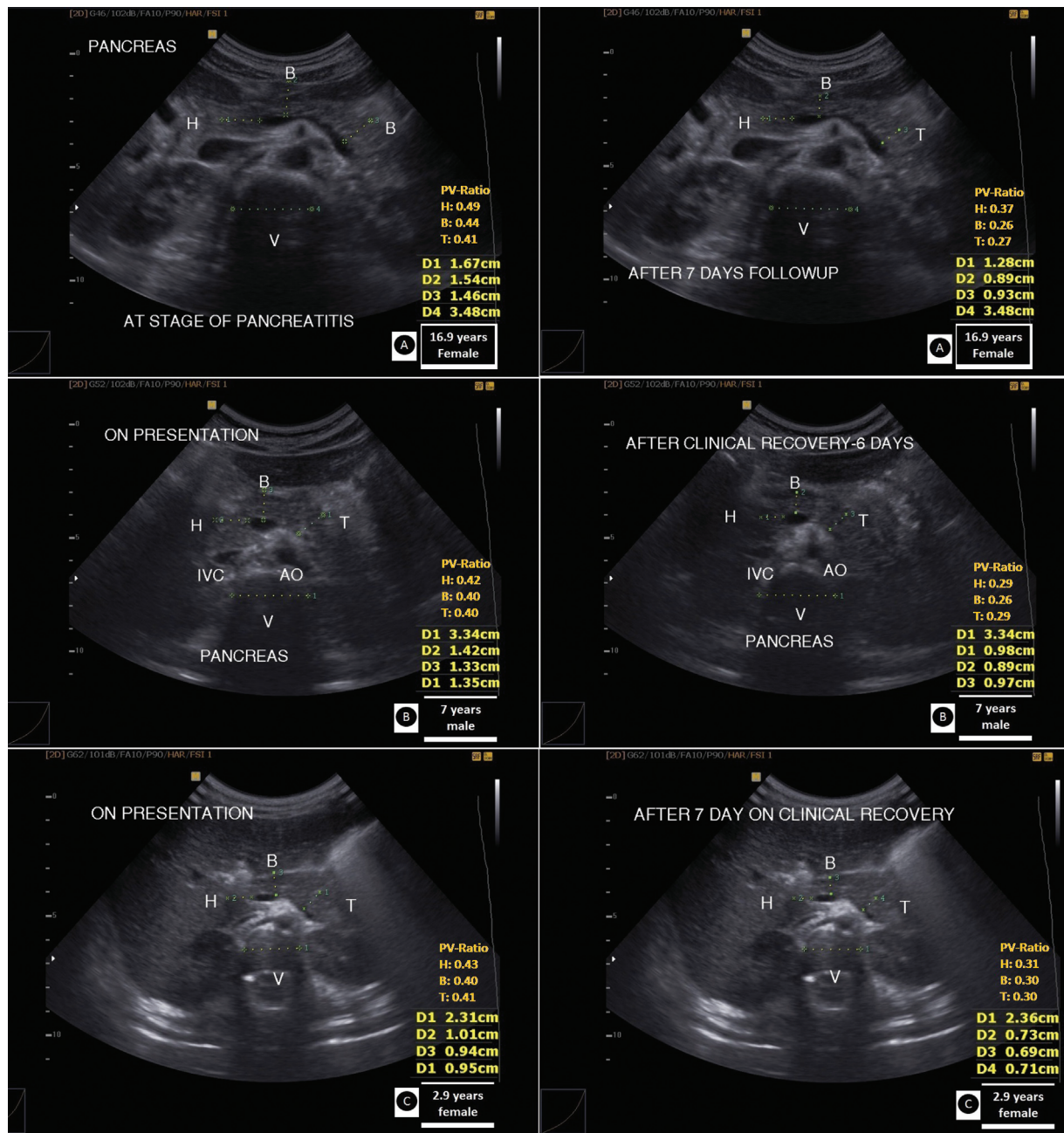
The descriptive statistics for demographic and anthropometric parameters were obtained for control and AP groups. The analyses of P/V ratio were performed sex-wise. The receiver operating characteristics (ROC) analysis was performed on P/V ratio for the head, body, and tail of the pancreas and the diagnostic strength of respective cutoffs in deciding enlargement was obtained. Since age has relevance to the size of the pancreas, it was considered as a covariate in the ROC analysis. Thus, age-adjusted ROC (AROC) analysis was performed on P/V ratio measurements of each pancreatic part. Conceptually, AROC is defined as

$$AROC(f) = P(1 - F_Z(Y_{DZ}) \leq f) \dots (1)$$

where  $Y$  is the marker (*head, body, and tail P/V ratio*),  $Z$  is the covariate (*age*), and  $D$  is the binary outcome (*AP = 0 or 1*).  $F_Z(Y_{DZ})$  represents the case observation with covariate value  $Z$  ( $Y_{DZ}$ ) standardized with respect to the control population with the same value of  $Z$ . The estimation of AROC requires estimation of  $F_Z$ , the distribution of the marker in controls as a function of  $Z$ . A linear model could be specified, i.e.,  $Y = \beta_0 + \beta_1 Z + \epsilon$ , for the control population. The error distribution could be estimated empirically using the residuals from the linear model. This would lead to a cumulative distribution function as

$$cdf_{DZ} = F((Y - \beta_0 - \beta_1 Z)/\sigma)$$

Accordingly, the cumulative distribution value  $cdf_{Dzi}$  for each individual case could be obtained. The age-adjusted ROC plots for each pancreatic part were obtained and the sensitivity at 90% specificity, the threshold errors, and the corresponding P/V ratio cutoffs were reported. The sensitivity across pancreatic regions was compared to arrive at the most reliable pancreatic region indicating enlargement in the disease condition. All the analyses were performed using *pcvsuite* library from R-2.15.3 (R Foundation for Statistical Computing, Vienna, Austria) programming tool.



**Fig. 1** Sample sonograms showing different pancreatic parts and lumbar vertebra at presentation and after clinical recovery for three patients. (A) The sonograms show the pancreatic dimensions on USG at presentation and after clinical recovery for a patient aged 16.9 years. The patient presented with severe pain in the epigastric region with vomiting for 2 days, along with epigastric tenderness and serum amylase level of 426.6 IU/L. (B) The patient is a 7-year-old boy who presented with severe pain in the epigastric region and persistent vomiting and serum amylase level of 1,420 IU/L. (C) The patient is a 2.9-year-old girl with severe epigastric pain with vomiting for 3 days, along with epigastric tenderness and serum amylase level of 440 IU/L.

## Results

The study involved 283 controls and 37 patients with AP following the INSPPIRE criteria. Characteristics such as age, sex, and anthropometric parameters were statistically insignificantly different between the two groups (► **Table 1**). The mean pancreatic measurements on the head, body, and tail parts were significantly higher in AP group compared with the control group ( $p < 0.0001$ ). Similarly, the mean P/V ratio

for these parts was significantly higher in AP group compared with the control group ( $p < 0.0001$ ). As the study focused on deciding the enlargement of the pancreas in disease condition referring to P/V ratio as marker, ROC analysis was performed on P/V ratio, independently for each pancreatic part and for both sexes. The effect of covariate, i.e., age, was considered in the analysis, resulting in age-adjusted ROC curves for each pancreatic part. The diagnostic strength of the marker on each part is summarized



**Table 1** Descriptive statistics for various characteristics of children in the two groups

Characteristics	Normal (n = 283)	Acute pancreatitis (n = 37)	p-Value
Age (y), mean ± SD	6.40 ± 4.56	7.74 ± 2.93	0.085 [NS] <sup>a</sup>
Sex, n (%)			
Male	161 (56.89)	18 (48.64)	0.342 [NS] <sup>b</sup>
Female	122 (43.11)	19 (51.35)	
Height (cm), mean ± SD	109.83 ± 28.61	119.21 ± 14.11	0.064 [NS] <sup>a</sup>
Weight (kg), mean ± SD	20.41 ± 13.22	20.09 ± 7.19	0.881 [NS] <sup>a</sup>
Pancreas dimension (cm), mean ± SD			
Head	0.89 ± 0.21	1.71 ± 0.63	<0.0001 [S] <sup>a</sup>
Body	0.86 ± 0.18	1.54 ± 0.46	<0.0001 [S] <sup>a</sup>
Tail	0.92 ± 0.20	1.53 ± 0.49	<0.0001 [S] <sup>a</sup>
PV ratio (cm), mean ± SD			
Head	0.34 ± 0.09	0.56 ± 0.18	<0.0001 [S] <sup>a</sup>
Body	0.33 ± 0.08	0.50 ± 0.14	<0.0001 [S] <sup>a</sup>
Tail	0.35 ± 0.09	0.50 ± 0.15	<0.0001 [S] <sup>a</sup>

Abbreviations: NS, not significant; S, significant; SD, standard deviation.

<sup>a</sup>Obtained using independent sample t-test.

<sup>b</sup>Obtained using chi-square test.

in **Table 2** and the corresponding ROC plots according to sex are shown in **Fig. 2**.

For males, the area under curve (AUC) was maximum for the head (93.6%), followed by the body (88.4%) and tail (80.3%). Thus, the head region showed the best difference of cases from the controls. The sensitivity at 90% specificity for the head was maximum (83.33%), followed by the body (71.17%) and tail (58.08%). The threshold error for the head was 0.098, indicating 90% of the observations had errors less than the threshold, and the corresponding P/V ratio was 0.43. Thus, a ratio of more than 0.43 for a male child for the head is suggestive of enlargement. The threshold errors for the body and tail part were higher than that of the head with lower sensitivities.

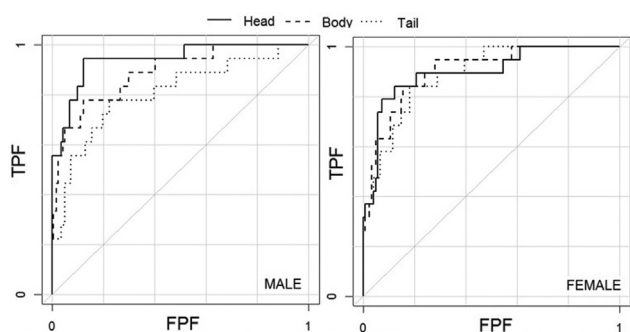
For females, the AUCs for the three parts were nearly similar; however, the sensitivity at 90% specificity for the head region was maximum (81.67%), followed by the body (72.33%) and tail (65.09%). The corresponding threshold error was 0.098, which was same as that for males. A P/V

ratio cutoff for the threshold error was 0.42, such that a ratio more than this is suggestive of head enlargement in female child. Thus, in females also, the diagnostic strength was better for the head region in comparison with the other two regions. In the present study, the enlargement was observed in 33 (89%) for head, 29 (78.4%) for body, and 30 (81.1%) for tail on day 1 of presentation, and 15 (40.1%) for head, 3 (8.1%) for body, and 12 (32.45%) for tail showed enlargement even after clinical recovery. The overall enlargement of the pancreas was observed in 35 (94.5%) cases on presentation and in 9 (24.3%) at clinical recovery (**Table 3**). The severity of AP in children as defined by the consensus committee was referred.<sup>4,10</sup> **Table 4** shows that out of 37 cases of AP, 14 (37.83%) had mild, whereas 5 (13.5%) had moderately severe AP and 18 (48.6%) had severe AP. In 10 (27.0%) cases, the first abdominal USG was performed within 48 hours of pain in the abdomen, in which 5 (50.0%) had mild AP, whereas 2 (20%) had moderately severe AP and 3 (30%) cases had severe AP. In 27 cases, the first USG was done after

**Table 2** Diagnostic strength of age-adjusted P/V ratio for the three pancreatic parts according to sex

Sex/part	AUC (%)	Sensitivity at 90% specificity (%)	Threshold error	P/V ratio cutoff
Male				
Head	93.6	83.33	0.098	0.43
Body	88.4	71.17	0.113	0.44
Tail	80.3	58.08	0.109	0.44
Female				
Head	89.3	81.67	0.098	0.42
Body	89.8	72.33	0.092	0.42
Tail	88.7	65.09	0.099	0.44

Abbreviation: AUC, area under curve.



**Fig. 2** Age-adjusted receiver operating characteristic curves for P/V ratio for male and female categories.

48 hours, out of which 9 (24.3%) had mild AP, 5 (18.5%) had moderately severe AP and 13 (48.1%) had severe AP. The enlargement in pancreatic size was detected by P/V ratio method in 35 cases, out of which 12 (32.4%) were mild, 5 (14.2%) moderately severe AP, and 18 (51.4%) were severe AP. There were 28 (80%) cases with global enlargement type, whereas 8 (20%) had patchy types. There were two (5.4%) mild cases in which enlargement was not detected using P/V ratio. Hypoechoogenicity was observed in 36 (97.3%) cases. In the second abdominal USG, the enlargement was observed in 13 (35.1%) cases, which were majorly from moderately severe and severe categories. All the cases had isoechogenicity after clinical recovery.

### Error Analysis

The scatter plots showing errors, i.e., the difference between observed and estimated values based on linear model, of the

three parts against age for the two study groups were obtained sex-wise (→ Fig. 3). For the AP group, the scatter plots were obtained *at presentation* and *after clinical recovery*. For controls, the mean error was close to zero with standard deviation of approximately 0.1 for all the three parts. At presentation, majority of the AP patients had error values above the threshold of the respective parts, indicating enlargement. In the figure, the distinction between error values of controls and AP at presentation is much clearer for head part as compared with body and tail, for both the sex categories. Therefore, the sensitivity for head was higher as compared with the other two parts in both the categories. After clinical recovery, the distribution of errors for all the regions nearly matched with that of controls as also evident from the figure.

### Discussion

The pancreas continues to grow until about 25 years of age.<sup>22</sup> The lumbar vertebral body lengths and widths constantly increase with age until maturation. Mavrych et al showed that the vertebral body size was independent of sex but correlated with the individual's age.<sup>24</sup> The P/V ratio remains consistent with age in normal children but it changes on higher side in AP patients because of the diffuse or focal enlargement of the pancreas in AP condition. In the present study, the overall total number of cases diagnosed with P/V ratio was 35 (94.5%). Earlier, Khanna et al<sup>15</sup> proposed a criterion based on body dimension of more than 1.5 cm, as indicative of enlargement in AP. Later, Siegel et al<sup>17</sup> suggested criterion based on statistical parameters. According to them, the dimension of any part exceeding 2 SD above the mean is

**Table 3** Enlargement of the pancreas in acute pancreatitis cases at first presentation and after clinical recovery using different methods ( $n = 37$ )

Method	First abdominal USG: first presentation <sup>a</sup>	Second abdominal USG: after clinical recovery <sup>b</sup>
Body > 1.5 cm (Khanna et al)	17 (45.9%)	1 (2.7%)
Mean ± 2 SD (Siegel et al)		
Head	25 (67.5%)	9 (24.0%)
Body	22 (59.4%)	1 (2.7%)
Tail	18 (48.6%)	3 (8.1%)
Total (global, patchy)	31 (83.7%) (15, 16)	9 (24.3%) (2, 7)
Percentile curves		
Head	14 (37.8%)	2 (5.4%)
Body	19 (51.3%)	1 (2.7%)
Tail	14 (37.8%)	2 (5.4%)
Total (global, patchy)	23 (62.1%) (11, 12)	2 (5.4%) (1, 1)
Body: P/V ratio > 0.3 (Fleishcher et al)	36 (97.2%)	19 (51.35%)
P/V ratio > 0.4 (present study)	Head: 33 (89.0%) Body: 29 (78.4%) T-30 (81.0%)	Head: 15 (40.5%) Body: 03 (08.1%) Tail: 12 (32.4%)
Total (global, patchy)	35 (94.5%) (28, 9)	9 (24.3%) (2, 7)

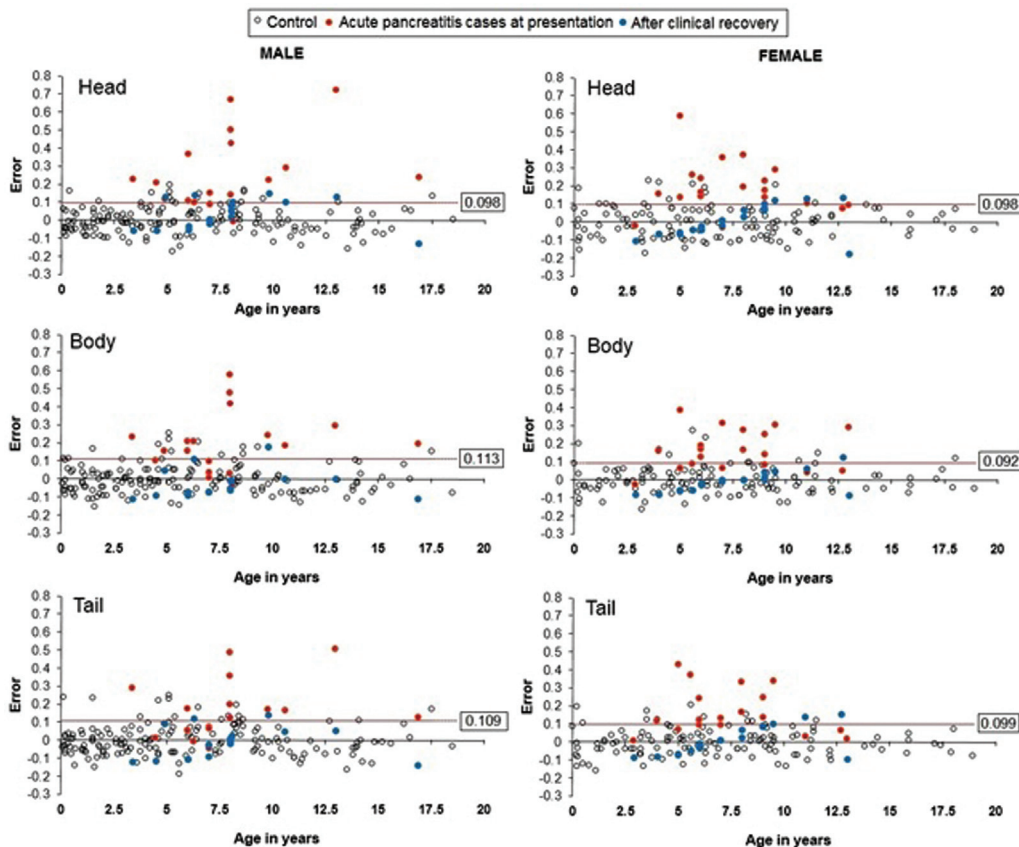
<sup>a</sup>Hypoechoogenicity was observed in 36 patients and hyperechogenicity in 1 patient.

<sup>b</sup>All 37 patients showed isoechogenicity.

**Table 4** Description of imaging outcome by P/V ratio according to severity of pancreatitis

Parameters	Acute pancreatitis			Total
	Mild	Moderately severe	Severe	
Total number of cases	14 (37.83%)	5 (13.5%)	18 (48.6%)	37
First abdominal USG on presentation				
Within 48 h	5 (50.0%)	2 (20.0%)	3 (30.0%)	10
After 48 h	9 (24.3%)	5 (18.5%)	13 (48.1%)	27
Enlargement by P/V ratio	12 (34.3%)	5 (14.2%)	18 (51.4%)	35
Enlargement type: global	9 (32.1%)	5 (17.8%)	14 (50.0%)	28
Enlargement type: patchy	3 (42.9%) [HB-2, HT-1]	1 (14.2%) [HT-1]	3 (42.8%) [HB-3]	7
No enlargement by P/V ratio	2 (100.0%) (USG within 48 h)	0	0	2
Echogenicity	Hypo 14 (38.9%)	Hypo 5 (13.8%)	Hypo, 17 (41.2%)	36
			Hyper 1 (2.7%)	1
Second abdominal USG on clinical recovery				
Enlargement by P/V ratio	0	5 (38.4%) (HT-5)	8 (61.53%) (Global: 0; H-5, BT-3)	13
Echogenicity	Isoechogenicity 14 (37.83%)	Isoechogenicity 5 (13.5%)	Isoechogenicity 18 (48.6%)	
Clinical recovery, mean (d)	6	8	11	

Abbreviations: B, body; H, head; T, tail; USG, ultrasonography.



**Fig. 3** Scatter plot showing sex-wise error occurrence with reference to age for three pancreatic parts in control and acute pancreatitis groups.

indicative of AP. Recently, Raut et al<sup>25</sup> developed percentile curves for each part based on data of normal children. As per the criterion by Khanna et al,<sup>15</sup> out of 37 children diagnosed with AP, 17 (45.9%) had enlargement on day 1, whereas 1 (2.7%) showed enlargement even after clinical recovery. The criterion by Siegel et al detected a maximum of 25 (67.5%) cases based on head dimension, followed by 22 (59.4%) using body and 18 (48.6%) using tail. After clinical recovery, head showed maximum cases (9; 24.3%) as still enlarged. The overall total number of cases diagnosed was 31 (83.7%). The percentile curves proposed by Raut et al<sup>25</sup> detected 19 (51.3%) cases with body dimension above the 95th percentile, followed by 14 (37.8%) on head and 14 (37.8%) on tail. The overall total number of the cases diagnosed was 23 (62.1%). As per the criteria by Fleischer et al,<sup>16</sup> out of 37 patients with AP, 36 (97.2%) had enlargement on day 1, while 19 (51.35%) showed enlargement even after clinical recovery based on body dimension. Fleischer et al gave the cutoff (0.3) on the basis of mean value for body part, whereas in the present study the cutoffs were obtained for each part with age-adjusted ROC analysis. The latter also provides the diffuse or patchy enlargement of the pancreas in disease condition, which is an advantage over Fleischer et al's method. Hence, in the present study, the maximum number (94.5%) of cases was diagnosed by P/V ratio in comparison

with earlier studies (except Fleisher et al), which could be an advantage for a clinician.

No enlargements by P/V ratio were observed in two mild cases with the first USG done within 48 hours; these two cases were associated with hypoechoogenicity. Similar observations were made by previous workers stating that nearly 20% or more of the children with AP had normal imaging, especially in the early or mild cases,<sup>10</sup> with a sensitivity of transabdominal US in detecting pancreatitis reported as 79.4%.<sup>10,13</sup> In such cases, it is proposed that further USG study may be undertaken after 24 to 48 hours to demonstrate the enlargement of the pancreas, if any, in the documented cases of AP. This method also revealed that global enlargement of the pancreas was observed in 28 (75.67%) and patchy enlargement in 7 (18.9%) cases. Patchy enlargement predominantly involved the head and body part of the pancreas. P/V ratio method further demonstrated that 13 (31.1%) cases continued to show enlargement after clinical recovery in the severe AP group and none in the mild AP group. Fleischer et al<sup>16</sup> stated that this may be due to residual effects of edema, hemorrhage, and fibrosis that occur as a result of pancreatic inflammation. This study also demonstrates that all cases of AP do not have enlargement on presentation and may remain within normal limits with hypoechoogenicity. However, on clinical recovery, there could be a reduction in the size of the pancreas with isoechoogenicity,

**Table 5** Etiological factors of acute pancreatitis in children ( $n = 67$ )

Etiology (male/female)	1 mo to 1 y	1–5 y	5–10 y	10–19 y	Total
	( $n = 1$ )	( $n = 13$ )	( $n = 38$ )	( $n = 15$ )	( $n = 67$ )
Idiopathic (unknown)		2/2	6/12	4/1	27 (40.3%)
Acute viral hepatitis A		0/2	2/3	0/2	9 (13.4%)
Mumps		0/2	1/1	1/0	5 (7.5%)
SCA					5 (7.5%)
SCA with vaso-occlusive crisis		1/0			1
Cholelithiasis			2/0		2
Choledocholithiasis				1/1	2
Typhoid fever		0/1	3/0	1/0	5 (7.5%)
<i>Salmonella typhi</i> : Hepatopancreatitis		0/1	1/1	0/1	4 (5.9%)
Traumatic			1/1	1/0	3 (4.4%)
Drug-induced					2 (2.9%)
Prednisolone		1/0			1
Valproic acid		1/0			1
Chronic diarrhea type 1* with broncho <sup>a</sup> Pneumonia with septicemia due to <i>Escherichia coli</i>	1/0				1 (1.5%)
Septicemia with DIC due to <i>E. coli</i>			0/1		1 (1.5%)
Acute hemorrhagic cystitis due to <i>E. coli</i>				0/1	1 (1.5%)
Choledochoceles				1/0	1 (1.5%)
Gastric Crohn's disease			1/0		1 (1.5%)
Recurrent acute pancreatitis			0/2		2 (2.9%)
Total	1	5/8	17/21	9/6	67

Abbreviations: DIC, disseminated intravascular coagulation; SCA, Sickle cell anemia.

<sup>a</sup>Chronic diarrhea type 1: diarrhea more than 2 weeks in a previously normal child.



as evident from the scatter plots. Similar observation in AP was made by Siegel et al,<sup>17</sup> who showed 54% cases of pancreatic measurements were normal.

In the present study, hypoechogenicity in 36 (97.29%) cases and hyperechogenicity in 1 (2.1%) case were observed at presentation, whereas isoechogenicity was observed in all the cases after clinical recovery. Fleischer et al<sup>16</sup> reported hypoechogenicity in 79% cases during AP and they observed that the decreased echogenicity of the pancreas was a reliable indicator of presence of pancreatitis in children. The idiopathic etiology was the commonest cause found in 40.3% of cases, and the age group 5 to 10 years was more susceptible to idiopathic etiology in the present study (►Table 5). The clinical recovery was noticed within 6 days in mild, 8 days in moderately severe, and 11 days in the severe AP. Werlin and Wilschanski<sup>4</sup> have reported recovery is usually complete within 4 to 5 days in mild AP.

There are some limitations of the present study: (1) inter-reader agreement could not be evaluated and (2) the number of diagnosed cases of AP is few due to low prevalence of AP and the single-center study design. Prospectively, we plan to involve multiple such hospital centers and strengthen the thresholds to comment on the pancreatic enlargement in AP and also ascertain patchy involvement. The enlargement criterion in conjunction with the clinical and biochemical test can be used for strengthening the diagnosis of AP in pediatric population.

## Conclusion

US is a good modality for demonstration of pancreatic enlargement in AP. It can be the first imaging choice in pediatric patients. A P/V ratio is an age-independent criterion and the diagnosis of AP can be done in 94.5% of cases. In routine practice, radiologist and clinicians can refer a cutoff value of a P/V ratio of greater than or equal to 0.4 for all parts with hypoechogenicity of the pancreas, which could be a typical imaging finding in the AP for both male and female patients.

### Declaration of Patient Consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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### Conflicts of Interest

There are no conflicts of interest.

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