Introduction
Gangrenous necrotic bowel (NB) is a difficult diagnosis to make clinically. Although most patients are usually septic and very ill, symptoms are highly variable, depending on the cause and the acuteness of onset of the underlying pathology. Ultrasound (US) is usually performed to evaluate children suspected of having NB. In good hands, US may diagnose the condition early enough to prevent significant morbidity and even mortality. This pictorial essay will illustrate a wide range of causes of NB and highlight the suspicious imaging findings on ultrasound. Correlation with plain radiographs, computed tomography (CT) and pathological specimens will be shown where available.

Learning Objectives
1. To familiarize the reader with a wide range of conditions that may cause NB in children.
2. To recognize the imaging features suspicious for NB that will help to diagnose the condition early.

Aetiology and Imaging findings
Common causes of NB in the neonatal period are necrotizing enterocolitis, malrotation and incarcerated inguinal hernia. In older children, intussusception, complications of Meckel’s diverticulum, post-surgical adhesions, internal hernias and vasculitic causes are more common. Imaging findings suspicious for NB are persistent dilated loops of thick-walled bowel, intramural gas, portal venous gas and pneumoperitoneum. Altered Doppler signals may be detected within the bowel. CT scans may show bowel wall thickening, focal or generalized bowel dilatation and variable contrast enhancement.

Case 1: Malrotation with mid-gut volvulus
A 6-day-old premature neonate (35 weeks gestational age) developed septic shock and bowel distension. Figure 2a and b. Serial AXRs over 6 hours show persistently dilated bowel loops throughout the abdomen. The jejunum is patent but the ileum appears collapsed (thick arrow). This is consistent with mid-gut volvulus. Figure 3a shows an AP myelo-contrast study with complete obstruction at the 3rd part of the duodenum (arrow) which is diagnostic of malrotation. Figure 4a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 4c shows the absence of the mesenteric vessels (thin arrows). Figure 4d and e. US shows the normal mesentery (thick arrow) adjacent to the bowel wall. The mesentery had normal Doppler signals.

Case 2: Necrotizing Enterocolitis
A 2-day-old neonate with sepsis and respiratory distress was noted to have feeding intolerance and persistent vomiting. Figure 5a and b. US shows hyperechogenicity of the bowel wall (thick arrow). Figure 5c shows the absence of intramural gas. Figure 5d and e. AXRs show dilated bowel loops throughout the abdomen. The jejunum is patent but the ileum appears collapsed (thick arrow). This is consistent with mid-gut volvulus. Figure 6a and b. US shows fluid in the peritoneal cavity. Figure 7a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 8a and b. US shows fluid in the peritoneal cavity. Figure 9a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 10a and b. US shows fluid in the peritoneal cavity.

Case 3: Segmental Necrotizing Enterocolitis
A 3-day-old premature neonate (37 weeks gestational age) developed septic shock and bowel distension. Figure 2a and b. Serial AXRs over 6 hours show persistently dilated bowel loops throughout the abdomen. The jejunum is patent but the ileum appears collapsed (thick arrow). This is consistent with mid-gut volvulus. Figure 3a shows an AP myelo-contrast study with complete obstruction at the 3rd part of the duodenum (arrow) which is diagnostic of malrotation. Figure 4a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 4c shows the absence of the mesenteric vessels (thin arrows). Figure 4d and e. US shows the normal mesentery (thick arrow) adjacent to the bowel wall. The mesentery had normal Doppler signals.

Case 4: Meckel’s Diverticulum with adhesion causing an Internal Hernia with Closed Loop Obstruction
A 2-month-old infant with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 8a and b. US shows fluid in the peritoneal cavity. Figure 9a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 10a and b. US shows fluid in the peritoneal cavity.

Case 5: Adhesive band causing bowel strangulation and necrosis
Figure 1a shows fluid in the peritoneal cavity. Figure 2a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 3a and b. US shows fluid in the peritoneal cavity. Figure 4a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 5a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 6a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 7a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 8a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 9a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 10a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized.

Case 6: Ileo-ileo-colic intussusception with necrotic terminal ileum
A 2-month-old infant with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 8a and b. US shows fluid in the peritoneal cavity. Figure 9a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 10a and b. US shows fluid in the peritoneal cavity.

Case 7: Henoch-Schonlein Purpura
Intussusception was seen in a small bowel, with necrosis. A non-contrast CT scan showed the presence of an intramural gas with a thickened bowel wall. Figure 1a shows hyperechogenicity of the bowel wall. Figure 2a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 3a and b. US shows fluid in the peritoneal cavity. Figure 4a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 5a and b. US shows fluid in the peritoneal cavity. Figure 6a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 7a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 8a and b. US shows fluid in the peritoneal cavity. Figure 9a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 10a and b. US shows fluid in the peritoneal cavity.

Case 8: Inguinal Hernia
In a 5-year-old child with a previous history of abdominal surgery presented with abdominal pain and vomiting. Cross section and long axis images show fluid in the peritoneal cavity. Figure 1a shows hyperechogenicity of the bowel wall. Figure 2a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 3a and b. US shows fluid in the peritoneal cavity. Figure 4a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 5a and b. US shows fluid in the peritoneal cavity. Figure 6a and b. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 7a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 8a and b. US shows fluid in the peritoneal cavity. Figure 9a and b. 4-year-old girl with acute onset of abdominal pain and vomiting. US shows hyperechogenicity of the bowel wall. The umbilical cord insertion point was not visualized. Figure 10a and b. US shows fluid in the peritoneal cavity.

Summary
In the appropriate clinical setting, NB should be suspected if the following features are noted on US:
1. Thickened bowel wall — may be hyperechogenic, hypoechoic or layered.
2. Air in the bowel wall appearing granular, faint or hypoechoic with posterior enhancement.
3. Hypoechoic appearance of the valvulae or “herringbone” pattern.
4. Colour Doppler signal may or may not be present in the bowel wall.
5. Fluid in the peritoneal cavity.

References