Intrahepatic and Portal Venous Gas Detected by Ultrasonography

T. Bömelburg¹ and H.-J. von Lengerke²

¹Kinderklinik und ²Institut für Klinische Radiologie der Universität Münster, Münster, Federal Republic of Germany

Abstract. During a 3-year period, sonographic evidence of portal venous gas (PVG) was found in 11 patients. Of these, 10 patients were examined for clinically suspected necrotizing enterocolitis (NEC). In the 11th patient, suffering from nephroblastoma, PVG was detected by routine sonography. Radiographic examination, performed in nine of 11 patients did not show any PVG. Intestinal pneumatosis was radiographically identifiable in only four of these children, whereas eight of 11 patients with sonographically detectable PVG also had sonographic evidence of intramural gas. Follow-up examinations in five patients showed cessation of PVG soon after onset of adequate therapy, indicating that ultrasonography is also a reliable method for monitoring NEC. Sonographic evidence of PVG, however, may be limited to the time before onset of therapy.

Key words: Necrotizing enterocolitis — Portal venous gas — Ultrasonography.

Radiological findings of portal venous gas (PVG) and intestinal pneumatosis are well-established signs indicating severe gastrointestinal disorders [1–3]. In neonates with clinically suspected necrotizing enterocolitis (NEC), such findings will confirm the diagnosis [4–6]. However, radiographic manifestation is not a constant finding and recognition can be difficult [1]. Ultrasonography, however, may detect PVG prior to any specific radiological abnormalities [7, 8]. So far, sonographic findings have rarely been reported in a greater series of infants, and little is known about the sonographical course.

We have retrospectively studied all infants examined by abdominal ultrasonography during a 3-year period for the finding of PVG. Patients, in whom gas bubbles were found, are presented herein.

Materials and Methods

At the University Children's Hospital at Münster, more than 3000 abdominal sonographic examinations (often including the gastrointestinal tract) are done each year. From January 1987 through March 1990, PVG was found in 11 patients (four girls, seven boys; body weight 1530 g to 22 kg). All of these patients but one were examined for clinically suspected NEC.

In all patients with PVG the clinical and radiological findings obtained within the period of sonographic examination and the eventual outcome were evaluated. Abdominal sonography was performed with a real-time computing system using a 3.5- or 5-MHz transducer (Acuson 128, Messrs. Acuson). Parenchymal organs were examined in standard planes. Bifurcation of the portal vein was routinely examined and documented on film. The gastrointestinal tract was screened in transverse and longitudinal planes. For clear imaging of the intestinal wall, intraluminal gas was moved by cautious massage with the transducer.

Results

The data of all 11 children showing PVG are listed in Table 1. Only one patient was examined for other reasons than clinically suspected NEC. The case history will be presented later, because of its unusual course.

Except in three children, who presented with symptoms of sepsis, only mild to moderate systemic and gastrointestinal signs were found. Fresh blood or guaiac-positive stools were present in eight of 11 infants. In three children inspection of stools for viruses was positive within 1 week after onset of symptoms.

Sonographically, gas bubbles were seen as high-amplitude echoes streaming through the portal vein in the hepatopetal direction (Fig. 1). By lowering the

Address offprint requests to: T. Bömelburg, M.D., Universitäts-Kinderklinik, Albert-Schweitzer-Strasse 33, W-4400 Münster, Federal Republic of Germany

Table 1. Clinical data of patients with portal venous gas

Patient body weight	Presenting symptoms and signs ^a	Day of study	Evidence of PVG					
			Sonographic			Radiographic		Therapy
			Pv	Liver	Mural	Pv	Mural	
GF (3510 g)	Moderate, bloody stools, CRP <0.6 Coronavirus	1	x	x	x	0	0	TPN/AB
		2	0	Focal	NI			
SB (2500 g)	Mild, bloody stools, CRP <0.6 Rotavirus	1	x	x	x	NI	NI	TPN/AB
		2	0	Focal	0			
		3	0	Focal	0			
		4	0	0	0			
FC (1570 g)	Mild, bloody stools, CRP <0.6 Coronavirus	1	x	x	NI	0	0	TPN/AB
		2	0	0	0			
		4	0	0	0			
PM (1530 g)	Severe, guaiac-negative stools, CRP 9.3	1	x	x	x	NI	NI	TPN/AB TPN Laparotomy: colonic strictures
		18	0	0	0			
		24		Ileus		Ileus		
RO (2770 g)	Moderate, guaiac-nega- tive stools, CRP 2.4	1	x	x	x	0	x	TPN/AB Laparot- omy: NEC
		2						
WE (2300 g)	Moderate, bloody stools	1	x	x	NI	0	x	TPN/AB
		2	0	Focal	0			
		4	x	x	NI	0	0	TPN/AB
		6	0	0	x	0	x	
		10	0	0	x			Laparotomy: colonic strictures
		30		Ileus		Ileus		
AS (3550 g)	Severe, guaiac-positive stools, CRP 1.2	1	x	0	x	0	x	TPN/AB
KK (3010 g)	Mild, guaiac-positive stools	1	x	x	x	0	0	TPN/AB
WL (1530 g)	Severe, bloody stools, CRP <0.6	1	x	x	NI	0	0	TPN/AB Laparot- omy: NEC
		2						
BM (1640 g)	Moderate, bloody stools, CRP <0.6	1	x	x	NI	0	x	TPN/AB Laparot- omy: NEC
		2						
GM (22 kg)	Moderate, guaiac-nega- tive stools, CRP 9.4	1	x	x	x	0	0	AB
		2	x	x	x			AB
		3	0	Focal	0			
		4	0	0	0			
		5						Laparotomy: NEC, pneumato- sis

Pv, portal vein; TPN, total parenteral nutrition; AB, antibiotics; NI, not investigated; NEC, necrotizing enterocolitis; CRP, C-reactive protein in mg/dl.

^a Grading of abdominal findings: mild, abdominal distention only; moderate, plus diminished or absent bowel sounds; severe, plus peritonitis or sepsis.

integration of imaging, the bubbles were also seen as pearl-like echoes ascending within the minor branches of the portal system. The hepatic parenchyma showed a characteristic varying pattern of focal hyperechogenicity (Fig. 2).

In nine of 11 infants radiologic examinations were performed on the same day. No patient had radiographic signs of PVG and only four children

showed intestinal pneumatosis. Sonography, however, demonstrated intramural gas in eight of 11 patients (Fig. 3). Follow-up sonographic examinations in five patients did not show any PVG 12–48 h after onset of adequate therapy (i.e., antibiotics and/or total parenteral nutrition).

None of the patients died of gastrointestinal injury, but laparotomy was performed in six children

Fig. 1. A, B High-amplitude echoes of gas bubbles streaming through the portal vein and accumulating within their minor branches.

Fig. 2. Longitudinal scan through the liver showing multiple hyperechogenic areas of trapped air within the hepatic parenchyma.

Fig. 3. Transverse scan through an intestinal loop showing intense reflections of intramural gas bubbles.

for rapid progression of NEC (three patients), tumor resection (one patient), or mechanical ileus later on (two patients).

Case History

A 6-year-old boy with suspected nephroblastoma, in poor clinical condition with fever (up to 39.5°C) and elevation of C-reactive protein (CRP, 14 mg/dl), was admitted to our hospital. After initiation of cytostatic therapy, CRP (5 mg/dl) slightly decreased, while intermittent fever persisted. One week later, the patient developed abdominal pain and another increase in CRP (9.4 mg/dl). Acute tumor necrosis or an abscess was excluded by emergency sonography. Three days later, PVG was detected by routine abdominal sonography for tumor staging. Only after the antibiotic regime had been modified 2 days later was PVG no longer detectable. Surgical resection of the tumor revealed intestinal abnormalities with pneumatosis and inflammatory signs, particularly of the left colonic flexure and the descending colon. After tumor resection, the patient's condition slowly improved.

Discussion

NEC represents a disorder with high mortality particularly among preterm infants [5, 6]. Severity of the disease varies within a wide range—from only

mild gastrointestinal disturbance to a rapidly developing course, often with fatal outcome [6]. For diagnosis and appropriate treatment, clinical staging criteria have been defined, which consider classical x-ray findings (i.e., intestinal pneumatosis and gas in the portal vein) [2, 4, 6].

Nevertheless, ultrasonography seems to be a more sensitive method for demonstration of gas in NEC. In contrast to the static x-ray pictures, gas bubbles are seen as high-amplitude echoes streaming through the portal system in the hepatopetal direction. However, when trapped in the liver, gas is seen as a pattern of focal hyperechogenicity, which can be easily differentiated from portal connective tissue by its brightness and the inhomogeneous position-dependent distribution. One should be aware that gas bubbles may form in the portal or caval vein, if an umbilical vein catheter or central venous line cannot be disconnected for the time of ultrasonography. Gas bubbles are markedly different from the low- and middle-amplitude echoes produced by the formed elements of blood [9]. Imaging of carbon dioxide in mineral water offers a representative impression and might serve as a standard for the sonographic devices used.

In our series, sonographic detected of PVG did not correlate with comparable radiographic findings. Similar results have been reported by Merritt et al. [7], who found hepatic gas or PVG without characteristic radiographic manifestation in five of 12 infants suffering from NEC. The sonographic signs often preceded radiographic abnormalities [7, 8]. Intramural gas, seen in eight of 11 of our patients with PVG, is thought to be the sonographic equivalent preceding radiologically detectable intestinal pneumatosis [10].

Abdominal distention and bloody stools are common initial signs of NEC [3, 5, 6]. These symptoms often led to ultrasonographic examination in our series, while laboratory data were unspecific. Viral gastrointestinal infection, especially in combination with bloody stools, does not exclude the diagnosis per se, as epidemic NEC has been reported with viral infections [6].

Rarely, sonographic evidence of gas bubbles has been reported in adult patients with severe bacterial infections. All had underlying inflammatory bowel disease (i.e., Crohn's disease and ulcerative colitis) [11, 12]. Additionally, one patient had been described to suffer from ischemic bowel necrosis following surgery of an abdominal aneurysm [13]. In our 6-year-old patient, the cytostatic treatment might have been a predisposing factor for the intestinal injury followed by exo- or endogenous bacterial overgrowth.

Progressive necrosis and ulceration of the mucosal and submucosal layers seem to be essential for the passage of gas into the portal venous system [1, 3]. So far, the pathomechanism of excessive intramural gas and PVG formation remains unclear. Intestinal bacterial overgrowth and/or bacterial fermentation of carbohydrates to hydrogen are discussed [2, 6]. This suggestion is supported by follow-up examinations in five of our patients which demonstrate cessation of PVG within 24–48 h after initiation of therapy (i.e., total parenteral nutrition and/or adequate antibiotics). These findings confirm

that ultrasonography is a reliable method for monitoring NEC. It is also obvious that evidence of PVG may be limited to the time before initiation of adequate therapy.

References

1. Arnon RG, Fishbein JF. Portal venous gas in the pediatric age group. *J Pediatr* 1971;79:255–259
2. Kosloske AM, Musemeche CA, Ball WS, Ablin DS, Bhattacharyya N. Necrotizing enterocolitis: value of radiographic findings to predict outcome. *AJR* 1988;151:771–774
3. Santulli TV, Schullinger JN, Heird WC, Gonagware RD, Wigger J, Barlow B, Blanc WA, Berdon WE. Acute necrotizing enterocolitis in infancy: a review of 64 cases. *Pediatrics* 1975;55:376–387
4. Bell MJ, Ternberg JL, Feigin RD. Neonatal necrotizing enterocolitis. Therapeutic decisions based upon clinical staging. *Ann Surg* 1978;187:1–7
5. Koloske AM, Musemeche CA. Necrotizing enterocolitis of the neonate. *Clin Perinatol* 1989;16:97–111
6. Walsh MC, Kliegmann RM. Necrotizing enterocolitis: treatment based on staging criteria. *Pediatr Clin North Am* 1986;33:179–201
7. Merritt CRB, Goldsmith JP, Sharp MJ. Sonographic detection of portal venous gas in infants with necrotizing enterocolitis. *AJR* 1984;143:1059–1062
8. Robberecht EA, Afschrift M, De Bel CE, Van Haesebrouck PJ, Van Bever HP, De Wit M, Leroy JG. Sonographic demonstration of portal venous gas in necrotizing enterocolitis. *Eur J Pediatr* 1988;147:192–194
9. Wolverson MK, Nouri S, Jolst JH, Sundaram M, Heiberg E. The direct visualization of blood flow by real-time ultrasound: clinical observations and underlying mechanisms. *Radiology* 1981;140:443–448
10. Vernacchia FS, Jeffrey RB, Laing FC, Wing VW. Sonographic recognition of pneumatosis intestinalis. *AJR* 1985;145:51–52
11. Conrad MR, Bregman R, Kilman WJ. Ultrasonic recognition of parenchymal gas. *AJR* 1979;132:395–399
12. Gosink BB. Intrahepatic gas: differential diagnosis. *AJR* 1981;137:763–767
13. Nachtegaele P, Afschrift M, Vandendriessche M, Van Rattinhe R, Voet D, Verdonk G. Sonographic diagnosis of gas embolism in the portal vein. *Gastrointest Radiol* 1982;7:375–377

Received: November 4, 1991; accepted: December 13, 1991