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Rectal luminal Pr_{CO_2}, measured by automated air tonometry, does not reflect gastric luminal Pr_{CO_2} in children

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Abstract
Rectal luminal regional P_{CO_2} (Pr_{CO_2}) was compared with gastric luminal Pr_{CO_2} measured by automated air tonometry at intervals of 10 min in 20 children aged 6–16 years scheduled for elective surgery under general anesthesia. In 5 patients, measurement of rectal Pr_{CO_2} failed because of catheter-related problems. In the remaining 15 children, aged 10.6 ± 2.5 years, 19 ± 7 paired rectal and gastric Pr_{CO_2} values (*n* total, 241) were measured. Bias and precision for gastric compared to rectal Pr_{CO_2} was −1.79 kPa and 2.89 kPa. In patients with obvious feces in the rectum, bias (precision) for gastric compared to rectal Pr_{CO_2} was −2.7 kPa (2.6 kPa) and in those with empty rectum, −0.75 kPa (1.42 kPa; *t*-test; $P < 0.001$). Based on our in vivo data, rectal luminal Pr_{CO_2}, measured by automated air tonometry, does not reflect gastric luminal Pr_{CO_2} in children. Enteral luminal gas production within feces in the rectum seems to be a major source of this disagreement.

Key words Tonometry · Gastric · Rectal · Children

Measurement of gastric luminal P_{CO_2} using tonometry represents a minimally invasive method to assess the adequacy of gut blood flow and splanchnic mucosal perfusion [1–4]. Automated continuous gastric air tonometry has been reported to detect circulatory failure earlier than conventional hemodynamics after cardiac surgery, and represents a simple method to continuously monitor gut perfusion in critically ill patients [3]. Recently, Bichel et al. [5] reported on the high sensitivity of gastric intramucosal pH for predicting outcome in pediatric cardiac surgery.

However, insertion of the currently available pediatric gastric tonometry catheters is often difficult, necessitating additional direct laryngoscopy; also, the feeding lumen is not sufficient to drain gastric fluid, and, during cardiac surgery, with manipulation of the transesophageal echocardiographic probe, the thin tonometry catheter may easily displace or kink.

In the present study, our purpose was to compare rectally measured luminal P_{CO_2} in children, using air tonometry, with gastric luminal P_{CO_2}.

With approval of the Hospital Ethics Committee and after obtaining written parental consent, 20 children, aged 6–16 years scheduled for elective orthopedic surgery under general anesthesia, with or without lumbar catheter epidural anesthesia, were included in the study.

After endotracheal intubation, a 14-Fr and an 8-Fr tonometry catheter (Tonometrics Catheter; Datex Ohmeda Division, Helsinki, Finland) were inserted oro-gastrically and rectally, respectively, and connected to two different air tonometers (TONOCAP; Datex-Engstrom, Tonometrics Division, Helsinki, Finland). Correct gastric placement of the catheter tip was confirmed by auscultation and aspiration of gastric fluid. The rectal catheter was inserted guided by a finger, after the application of lubricating gel, and was taped to the thigh afterwards. Care was taken to place the catheter balloon proximal to the rectal sphincter muscle, by applying a safety mark 5 cm proximal from the proximal end of the catheter and inserting the catheter until the mark was placed at the level of the sphincter muscle. The absence or presence of feces in the rectum was noted in each patient, depending on obvious feces on the examination glove after the catheter had been inserted. The two TONOCAP devices used in the study were calibrated, using Datex calibration gas with 5% CO_2 content, according to the manufacturer's instructions, and were used in randomized order between subjects. Rectal and gastric regional P_{CO_2} (Pr_{CO_2}) values were noted at intervals of 10 min after obtaining steady-state values. Rectal and gastric Pr_{CO_2} values were com-

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Table 1. Pr_{CO_2} values in children undergoing general anesthesia for orthopedic surgery

	All	+ Feces	– Feces	+ Epidural anesthesia	– Epidural anesthesia
Patients (*n*)	15	8	7	8	7
Mean Pr_{CO_2} (kPa)	6.15	6.81	5.41	6.31	5.96
SD Pr_{CO_2} (kPa)	1.5	1.79	0.40	1.93	0.71
Bias gastric-rectal Pr_{CO_2} (kPa)	–1.79	–2.70	–0.75	–1.89	–1.66
Precision gastric-rectal Pr_{CO_2} (kPa)	2.89	2.60	1.42	3.27	2.35
95% Limits of agreements of Pr_{CO_2} (kPa)	3.26–9.04	4.21–9.41	3.98–6.83	3.04–9.58	3.62–8.31
n measurements	241	128	113	130	111
t-test		$P < 0.001$		$P = 0.263$	

Bias (mean difference) and precision (2 SD of the difference) of gastric compared to rectal Pr_{CO_2} measurement are shown, as well as comparisons of gastric and rectal Pr_{CO_2} in patients with and without feces in the rectum and of patients with or without epidural anesthesia (combined with general anesthesia)

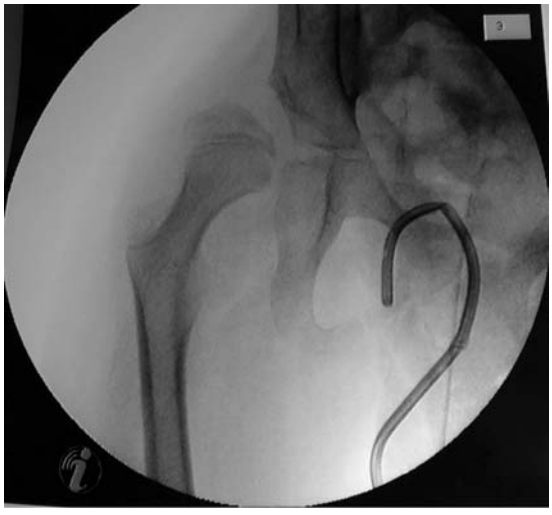

Fig. 1. Intraoperative X-ray of a rectally inserted 8-Fr tonometry catheter with kinking during orthopedic surgery, causing catheter alarm on the air tonometer device and failed assessment of regional P_{CO_2} (Pr_{CO_2})

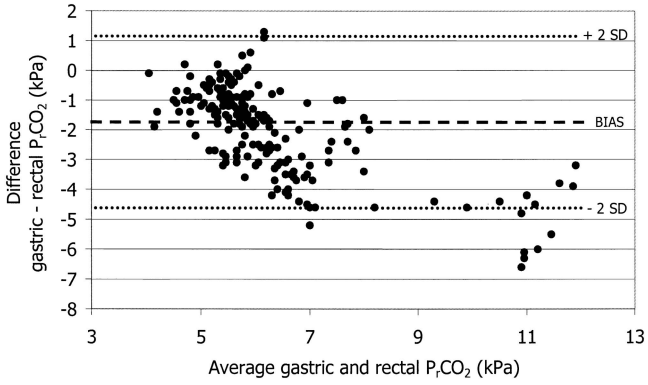

Fig. 2. Bland-Altman plot for the comparison of gastric and rectal Pr_{CO_2} in 15 patients ($n = 241$ measurements)

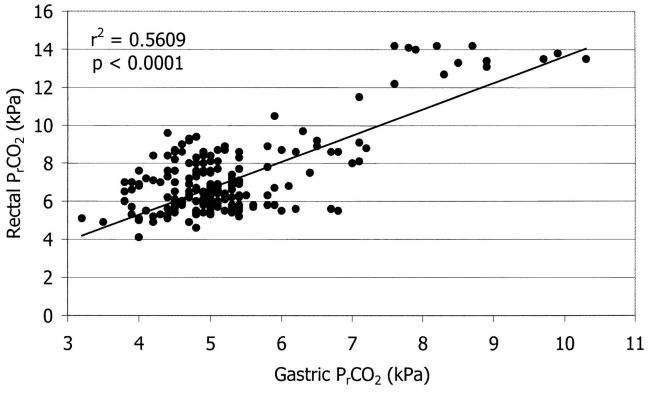

Fig. 3. Linear regression diagram for the comparison of gastric and rectal Pr_{CO_2} in 15 patients ($n = 241$ measurements)

pared using Bland-Altman bias analysis and linear regression analysis. Paired two-sided Student's *t*-test was used to compare subgroup values from patients with obvious feces in the rectum to values from patients without obvious feces in the rectum and to compare values from patients with and without epidural anesthesia. A *P* value of less than 0.05 was considered statistically significant.

In 5 patients, measurement of rectal Pr_{CO_2} failed because of catheter-related problems, most of them due to obstructed sampling of the lumen caused by catheter kinking (Fig. 1). In the remaining 15 children, aged 10.6 ± 2.5 years, 19 ± 7 paired rectal and gastric Pr_{CO_2} values (*n* total, 241) were measured (Table 1). Gastric Pr_{CO_2} values ranged from 3.2 kPa to 10.3 kPa, and rectal Pr_{CO_2} values ranged from 4.1 kPa to 14.2 kPa. Bias (mean difference) for gastric compared to rectal Pr_{CO_2} was –1.79 kPa and precision (2 SD of mean difference) was 2.89 kPa, with a trend to larger differences with higher Pr_{CO_2} values (Fig. 2). No relevant correlation was found between tonometrically measured gastric and rectal luminal Pr_{CO_2} ($r^2 = 0.561$; $P < 0.0001$; Fig. 3). Intraindividual bias ranged from –4.77 to –0.33 kPa, and precision ranged from 0.29 to 3.32 kPa. In patients with obvious feces in the rectum, bias (precision) for gastric compared to rectal Pr_{CO_2} was –2.7 kPa (2.6 kPa) and in those with empty rectum, –0.75 kPa (1.42 kPa) (*t*-test;

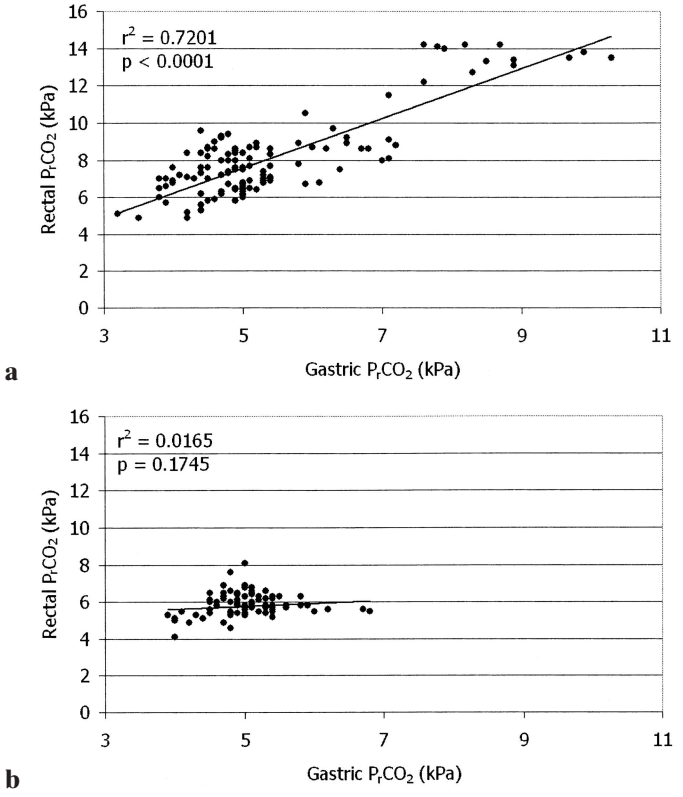

Fig. 4. Linear regression plots for the comparison of gastric and rectal Pr_{CO_2} in **a** patients with rectal feces ($n = 8$) and **b** without feces ($n = 7$); $n = 128/113$ measurements

$P < 0.001$). Simple regression plots for the comparison of gastric and rectal Pr_{CO_2} in patients without and with rectal feces are shown in Fig. 4. No significant difference in the gastric to rectal Pr_{CO_2} was found for patients with ($n = 8$) and without ($n = 7$) continuous epidural anesthesia ($P = 0.263$).

The first clinical studies on monitoring intestinal luminal Pr_{CO_2} were performed in the sigmoid colon and have been reported to be even more specific for the prediction of major complications after abdominal aortic surgery than gastric intestinal pH [6,7]. Rectal insertion of a tonometry catheter is similar to the insertion of a rectal temperature probe, which is a standard procedure in pediatric anesthesia. In this way, rectal tonometry could be a noninvasive monitor of splanchnic perfusion in the patient at risk for global hypoperfusion [8] and a predictor of metabolic state and complications [5].

In this preliminary study, we compared gastric with rectal luminal Pr_{CO_2}, using air tonometry, in children undergoing orthopedic surgery. The main finding was that there was no agreement between the two sites of measurements, with higher values for Pr_{CO_2} in the rectal lumen than in the gastric lumen. Second, a larger disagreement between gastric and rectal Pr_{CO_2} was found at higher Pr_{CO_2} values (Fig. 2). The second finding could probably explain the higher accuracy of bowel Pr_{CO_2} compared to gastric Pr_{CO_2} to predict major complications after abdominal surgery, whereas the main finding is related to feces in the rectum as an important source of CO_2 production.

Gas in the intestine consists mainly of N_2 (90%), CO_2, O_2, CH_4 (methane), and trace gases [9]. Intestinal gas is mainly caused by swallowing air (5–10 ml per swallow), but only 400 ml passes to the intestine per day [10]. Bacterial fermentation of nonresorbable hydrocarbons and glycoproteins, which represent about 20% of the normal oral intake into the colon, leads to the production of CO_2 [11, 12]. In young children, fermentation, particularly of raw starch, is a more rapid process than in adults [13]. Macfarlane et al. [14]. have demonstrated significant inter-individual differences in fermentation reactions in different regions of the large bowel; namely, the cecum, colon, sigmoid, and rectum. These differences may have an impact not only on rectal luminal CO_2 measurement but also on the results of sigmoid tonometry [6, 7, 15].

Based on our in vivo data, rectal luminal Pr_{CO_2}, measured by automated air tonometry, does not reflect gastric luminal Pr_{CO_2} in children. Enteral luminal gas production within feces seems to be a major source of this disagreement.

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