

DUODENAL MOTILITY IS NOT AFFECTED DURING DUODENOTOMY IN PIGS

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The effects of surgical procedures on intestinal motility are still under debate. In order to quantify the effects of duodenotomy on duodenal motility, the present study used the electric impedance technique (IMP). Ten pigs (32–40 kg) were instrumented under general anaesthesia with a central venous catheter (CVC) and a percutaneous enterogastrostomy (PEG). Duodenal phases I–III and the duration of the migrating motor complex (MMC) were measured by an IMP catheter, which was introduced non-invasively into the proximal duodenum via the PEG by endoscopy, or through surgical placement in an invasive manner via duodenotomy. There were no significant differences in the length of interdigestive phases I–III between the groups. In tendency, pigs after laparotomy and duodenotomy demonstrated slightly prolonged median duration of phase I ($P = 0.1$) and phase III ($P = 0.7$), while phase II ($P = 0.1$) and the MMC cycle length ($P = 0.6$) seemed to be shortened as compared to pigs of the PEG group. In conclusion, simple laparotomy with duodenotomy did not affect the proximal duodenal motility activity measured by the impedance technique.

Key words: Duodenotomy, duodenal motility, electric impedance, migrating motor complex

Both intraoperative manipulations of the intestine and the duration of the operative procedures were reported to influence the severity of a postoperative

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ileus (Nachlas et al., 1972). In contrast, various surgical procedures demonstrated that the gastroduodenal duration and pattern of postoperative ileus were independent of the extent and duration of the surgical procedures performed (Graber et al., 1982). In order to investigate idiopathic effects of standardised surgical procedures on gastroduodenal motility, further studies are necessary.

The intraluminal impedance technique has recently been validated and allows the determination of gastroduodenal motility patterns through the acquisition of electric impedance in the surrounding body volume conductor from a number of annular electrodes (Silny, 1991; Imam et al., 2004). The passage of air or gas results in a temporary increase in intraluminal impedance while the passage of electrolytic mass is followed by a decrease in impedance (Savoye-Collet et al., 2003). The accuracy of impedancometry was confirmed by comparing the results of gastroduodenal peristalsis using video-fluoroscopy and manometry with those obtained by the impedance technique (Imam et al., 2004). Thereby, impedancometry promotes the measurement of motility activity independent of intraluminal pressures. Thus, the impedance technique might detect the activity of intestinal motility more precisely than manometry (Savoye-Collet et al., 2003).

In order to investigate the effects of laparotomy in conjunction with duodenotomy on duodenal motility, the current study used the impedance technique in anaesthetised pigs.

Materials and methods

Subjects

This investigation was approved by the local Institutional Animal Ethics Committee. In order to avoid gender bias on intestinal motility we studied ten male castrated German Landrace pigs with body weights (BW) between 32 and 40 kg, which were all obtained from the same breeder. Over a period of nine days, the pigs were allowed to adjust to both the local housing conditions and the investigators (Schnoor et al., 2003). The pigs had free access to water and were fed twice a day with a standard diet as required to maintain weight (Muskator[®], Muskator-Werk, Germany).

Instrumentation

Each pig was fasted overnight but still had free access to water. After premedication with 4 mg·kg⁻¹ azaperone (Stresnil[®], Janssen-Cilag GmbH, Germany) and 0.5 mg atropine (Atropin[®], B. Braun Melsungen, Germany) i.m., 10 mg·kg⁻¹ ketamine (Ketamin[®], Sanofi-Ceva GmbH, Germany) was injected i.m.. Once intravenous access had been established, general anaesthesia was subsequently induced intravenously with 2–4 mg·kg⁻¹ propofol (Propofol[®], Parke-Davis, Germany). Anaesthesia was maintained with a continuous infusion of 20–

25 mg·kg⁻¹·h⁻¹ propofol and 0.5 mg·kg⁻¹·h⁻¹ (S)-ketamine ((S)-Ketanest[®], Parke-Davis, Germany). The pigs underwent orotracheal intubation and were mechanically ventilated. Oxygen saturation (SaO₂) of 94–99% and expiratory carbon dioxide partial pressures (p_{ET}CO₂) of 35–38 mm Hg were maintained. Fluid was replaced during surgery with a crystalloid solution at a rate of 2 ml kg⁻¹ h. Blood pressure was measured through non-invasive methods on the hindlimb (Riva-Rocci; AS/3 Compact[®], Datex-Engstrom, Finland and Dura Cuff[™], Infant Cuff, Criticon, USA). Mean arterial blood pressures (MAP), heart rate (HR), SaO₂, and p_{ET}CO₂ were assessed at 15-min intervals during the surgical procedure. The animals were instrumented with a central venous catheter (CVC) inserted into the left jugular vein via venous cut-down. The catheter was then tunnelled paravertebrally and subcutaneously towards the neck. All pigs were then instrumented with a percutaneous enterogastrostomy (PEG, GastroPEG[®], B. Braun Melsungen, Germany) which was performed through endoscopy (Olympus Optical GmbH & Co. KG, Germany). The end of the PEG was tunnelled paravertebrally and subcutaneously towards the back. Povidone-iodine solution was instilled into the subcutaneous tunnels. The body temperature (Temp) and the white blood cell count (WBC) were determined twice a day.

Protocol

The pigs were divided into two groups: In Group A (n = 5), gastroscopy was subsequently performed and the impedance catheter (2 mm in diameter, 100 cm in length, flexible, 16 succeeding measuring segments of 2 cm length each distributed over the distal 32 cm, Femu-Research Institute, Aachen, Germany) was introduced via the PEG into the duodenum by endoscopy. In contrast, in the pigs of Group B (n = 5), duodenoscopy was performed only. Finally, the CVC, the PEG, and the impedance catheter (Group A only) were placed into a catheter bag, which was sutured onto the back. Postoperative analgesia was already started under general anaesthesia with the first dosage of a non-opioid analgesic metamizol sodium 20 mg·kg⁻¹ (Novalgin[®], Hoechst, Germany) given i.v., and carprofen 4 mg·kg⁻¹ (Rimadyl[®], Pfizer GmbH, Germany) given s.c. Finally, the pigs were extubated. All pigs were then fed a standard diet in the evening and had free access to water overnight.

The next morning, the pigs were transported to the laboratory after routine morning feeding. General anaesthesia was started with a bolus of 2–4 mg·kg⁻¹ propofol followed by the continuous infusion of 25–30 mg·kg⁻¹·h⁻¹ propofol, and of 2–4 µg·kg⁻¹·h⁻¹ fentanyl via the CVC. The pigs underwent orotracheal intubation and were mechanically ventilated. Oxygen saturation (SaO₂) of 94–99%, and expiratory carbon dioxide partial pressures (p_{ET}CO₂) of 35–38 mm Hg were maintained. The dose of anaesthetics was adjusted according to the clinical signs indicating the depth of anaesthesia. Fluids were replaced with a 2 ml·kg⁻¹·h⁻¹ crystalloid solution. In Group A, measurements of duodenal motility were started af-

ter an equilibration time of 30 min. In contrast, the pigs of Group B underwent laparotomy of the right-sided upper abdominal wall (incision length 11–13 cm) followed by an anti-mesenteric incision of the proximal duodenum 5–10 cm aboral the pylorus. The catheter for impedancometry was introduced aboral into the duodenum and both the duodenum and the abdominal wall were closed by manual sutures before measurements were started (see Fig. 1). The duodenal motility activities were then recorded for the following 4 h. At the end of the measurements the animals were euthanised by an overdose of barbiturate. Necropsy was subsequently performed.

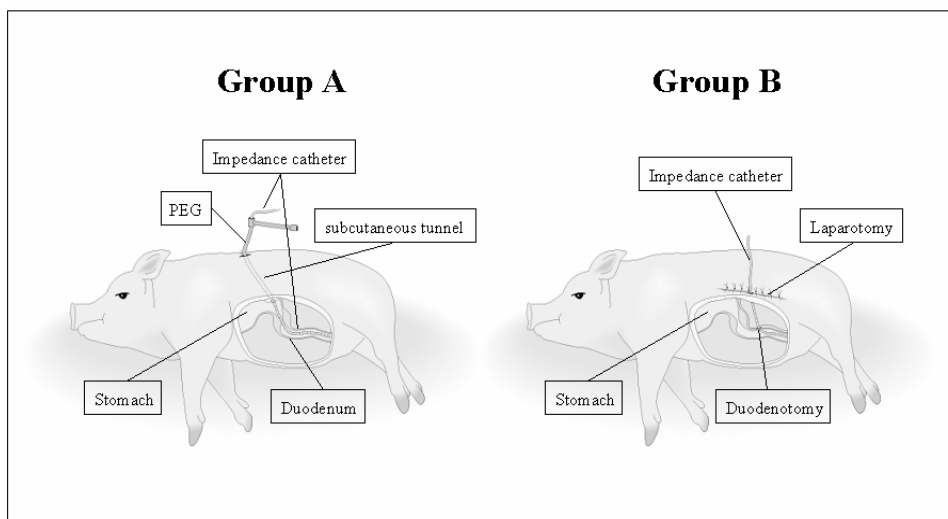


Fig. 1. Instrumentation of the two groups. Pigs of Group A were instrumented with an impedance catheter that was introduced into the proximal duodenum via a percutaneous enterogastrostomy (PEG) by endoscopy. In contrast, the pigs of Group B underwent laparotomy and duodenotomy in order to introduce the catheter for impedancometry manually. Note that in Group B the PEG is not shown for the sake of better demonstration

Impedancometry and derived parameters

Duodenal motility activity was assessed by impedancometry (see Fig. 2). Impedance signals were recorded and stored online on a laptop (Toshiba Satellite Pro 4030). The impedance tracings were visually analysed on a PC screen. A locally developed software (Femu-Research Institute, University Hospital Aachen, Germany) was used for data acquisition, analysis, and graphic presentation. Duodenal motility activity was defined as waves that demonstrate a drop from the baseline of more than 30%. Fasting digestive motility is normally characterised by the periodic occurrence of the migrating motor complex (MMC). The MMC is conventionally divided into three phases: the period of quiescence

(phase I) is followed by an irregular contractile activity (phase II), which is replaced by a shorter period of regular contractions termed phase III or 'activity front' of the MMC (Malagelada et al., 1986). According to established manometric criteria the MMC was defined as the time interval between two successive phase III patterns. The duodenal motor patterns were defined as described by Nguyen et al. (1995). According to established manometric criteria the interdigestive MMC was defined as the time interval between two successive phase III patterns. A bolus transport event (BTE) was defined as a delayed impedance drop in three or more consecutive tracings. Such an event is related to a bolus passage along the concerned channels as described by Nguyen et al. (1995) (see Fig. 3).

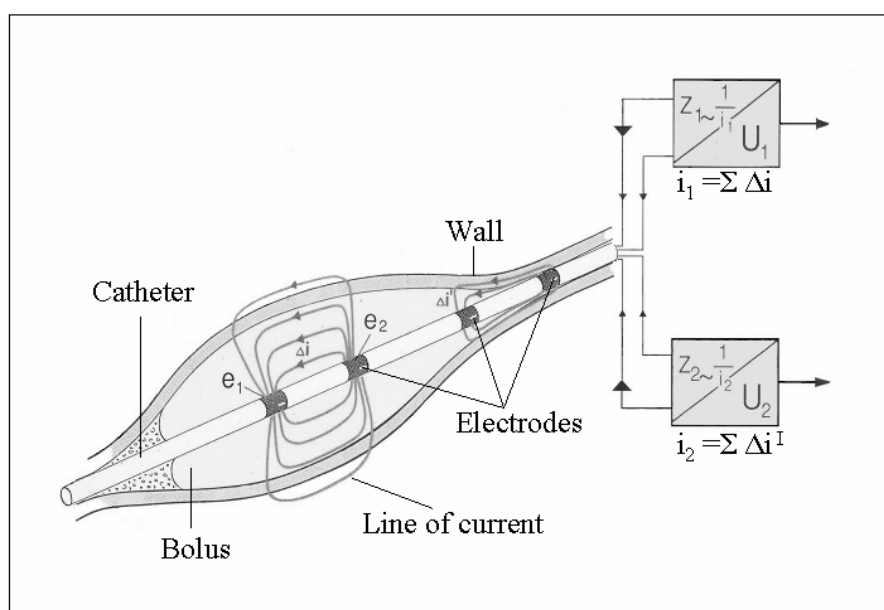


Fig. 2. Cylinder-shaped metallic electrodes (e) are mounted on a thin plastic catheter, which was introduced intraluminally (Wall). Each neighbouring electrode pair is connected to an impedance voltage transducer outside the body (not shown). Z_n = measured impedance of an electric field between two electrodes at the moment, which is the ratio between the applied voltage (U) and the resulting current (I). The instantaneous output voltage of each transducer represents the average electrical impedance of the volume conductor around the catheter (Line of Current). The impedance changes inversely to the diameter of the bolus during passage in distal direction

Statistical analysis

Statistical analysis was performed using statistical software (NCSS[®], NCSS Statistical Software, USA). Differences between the groups were analysed using the Wilcoxon Rank-Sum test. Data are expressed as medians and range. Significance was defined as $P < 0.05$.

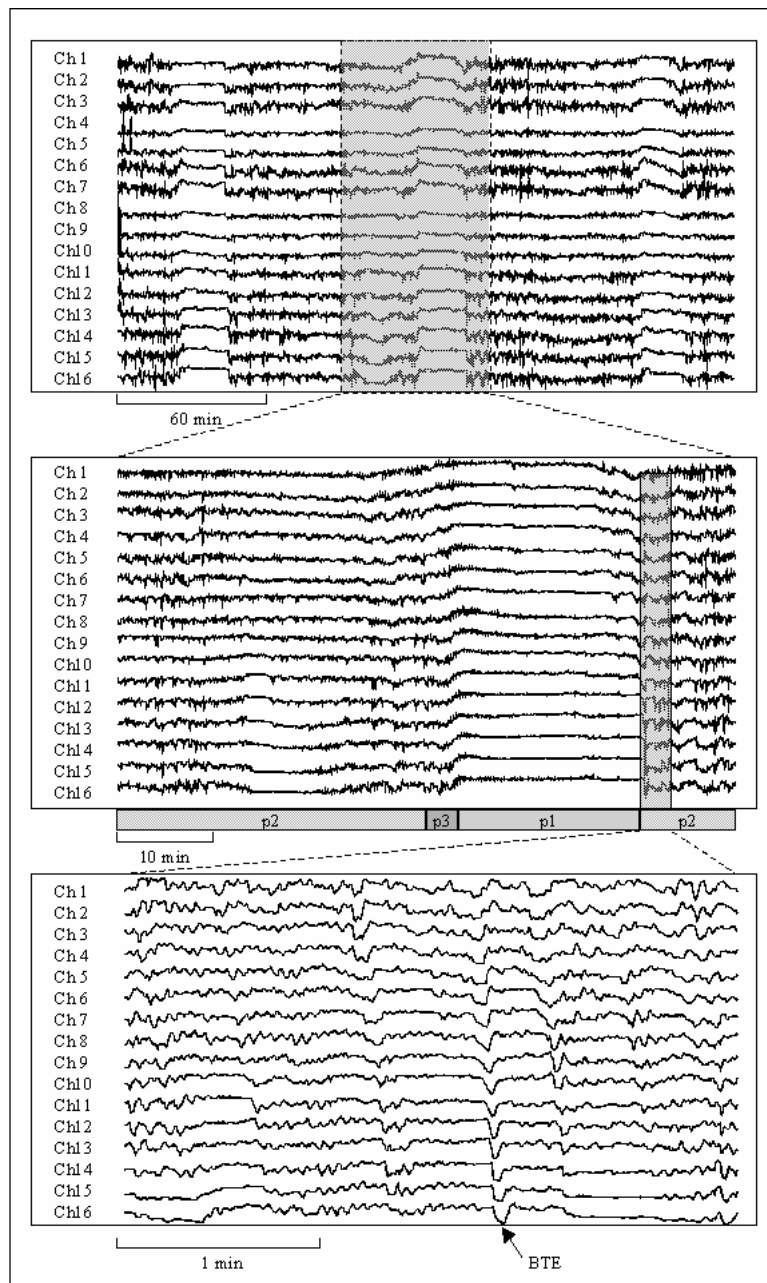


Fig. 3. Impedance tracings of a pig of Group B. Tracings represent impedance change in 16 consecutive measuring segments (Ch 1 = proximal channel 1; Ch 16 = distal channel), each 2 cm long. Top: time period of 4 h demonstrating interdigestive phases. Middle: complete MMC cycle distracted, p1 = phase I, p2 = phase II, p3 = phase III. Bottom: a part of phase II further expanded demonstrating a bolus transport event (BTE)

Results

The MMC cycle with its components (phases I–III) were identified. Phase I was characterised by small changes of impedance amplitudes. During phase II, irregular changes of impedance amplitudes, indicating a more irregular motor activity, were recorded. In contrast to phase II, the typical high-frequency changes of impedance amplitudes prior to phase I indicated phase III. An interdigestive recording with various motility patterns is demonstrated in Fig. 3.

There were no significant differences in the length of interdigestive phases I–III between the groups. In tendency, pigs after laparotomy and duodenotomy (Group B) demonstrated slightly prolonged median duration of phase I ($P = 0.1$) and phase III ($P = 0.7$), while phase II ($P = 0.1$) and the MMC cycle length ($P = 0.6$) seemed to be shortened as compared to pigs of the PEG group (Group A). The median duration of interdigestive phases I–III and MMC cycles are demonstrated in Fig. 4.

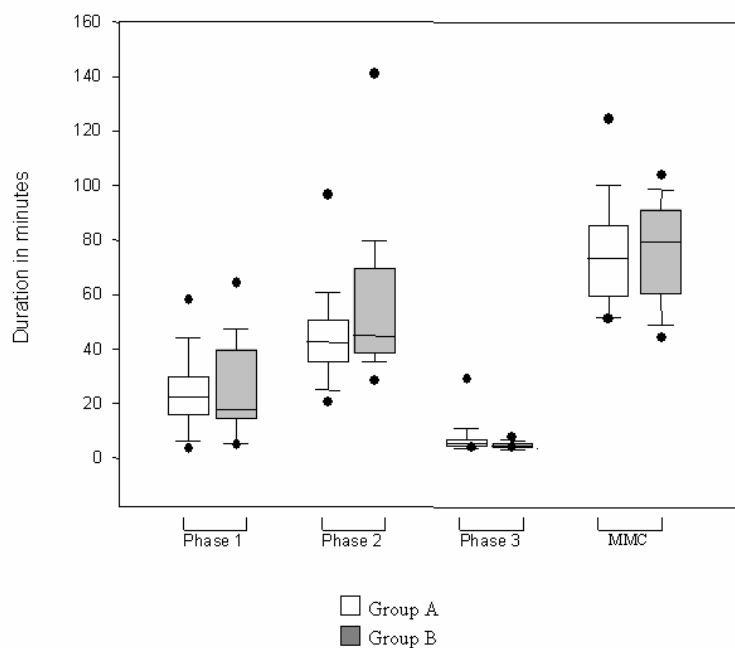


Fig. 4. Duration of interdigestive phases I–III and MMC cycle length of the two groups. Data are shown as box blots indicating median, 25% and 75% quartiles, and range

In both groups, the bolus transport events (BTE) could exclusively be detected during phase II. The number of BTE did not differ between both groups ($P = 0.1$). The number of BTE per phase is shown in Table 1.

Table 1

Duodenal bolus transport events (BTE) per phases I–III.
Data are expressed as medians and range

	Group A	Group B	P
Phase I	0	0	1.0
Phase II	48 (12–96)	61 (14–266)	0.1
Phase III	0	0	1.0

Demographic data such as body weight and age were comparable between the groups. The haemodynamic values and gas exchange parameters did not differ between the groups. The pigs in Group A demonstrated slightly higher body temperatures (Temp) than the pigs in Group B ($P < 0.05$). Necropsy showed full gastric contents consisting of the gastric intake being fed in the morning. In addition, the small intestine demonstrated a lack of any food migration. Demographic data are shown in Table 2.

Table 2

Demographic data (median and range): BW = body weight; HR = heart rate; MAP = mean arterial blood pressure; RR = respiratory rate; $p_{ET}CO_2$ = expiratory carbon dioxide partial pressure; SaO_2 = oxygen saturation; Temp = temperature; Hct = haematocrit; WBC = white cell count. Significance (*) is defined when $P < 0.05$

	Group A	Group B
BW (kg)	33.6 (30.7–38.9)	35 (32–36.5)
HR (/min)	106 (93–136)	99 (94–149)
MAP (mmHg)	82.3 (71–104)	101 (83–128)
RR (/min)	28 (22–29)	24 (21–25)
$p_{ET}CO_2$ (mmHg)	37 (35–38)	40 (37–41)
pH	7.39 (7.36–7.5)	7.4 (7.34–7.48)
SaO_2 (%)	99 (97–99)	98 (96–99)
Temp (°C)	39.2 (38.2–39.7)*	37 (36.5–39.6)
Hct	0.26 (0.25–0.34)	0.27 (0.25–0.28)
WBC ($\times 10^9/l$)	19.1 (14–24.4)	19.5 (11.2–25.5)

Discussion

The present study suggests that right-sided laparotomy in conjunction with duodenotomy did neither influence the duration of the duodenal interdigestive phases I–III nor the length of the MMC cycle in a significant manner.

Several factors contribute to a postoperative ileus. Besides sympathetic and parasympathetic activity, the release of inflammatory mediators with infiltra-

tion of inflammatory cells in the intestinal wall, anaesthetics, and opioids, the extent of the actual surgical manipulation might also show an inhibitory effect on intestinal motility (Puig et al., 2000; Kurz and Sessler, 2003). A postoperative ileus occurs mainly after abdominal and pelvic surgery, but may also be present after any type of surgery. In humans, the average postoperative time period of delayed gastrointestinal transit persists for less than 24 h in the small intestine, 24–48 h in the stomach, and for 48–72 h in the colon. Also, its duration seems to depend on the anatomic location of the surgery, with colonic manipulations being associated with the longest-lasting ileus. Clinically, a postoperative ileus is characterised by a lack of bowel sounds, delayed time of first flatus and stools, and bowel distension. Frequent symptoms are nausea and vomiting (Holte and Kehlet, 2000).

The occurrence of the migrating motor complex (MMC) during the fasted state in dogs was first described by Szurszewski (1969). The MMC is a cyclically occurring pattern of electric and mechanical activity that is initiated in the stomach and duodenum and propagates over the full length of the small intestine in most mammals including humans. MMC occurs only in the fasted state in dogs, humans, calf, horse and the opossum, and in both the fed and fasted state in the rat, rabbit, sheep and pig (Telford and Sarna, 1991).

After laparotomy, Smith et al. (1977) found a loss of motor activity of the MMC in the small bowel for 24 h in the dog. Others also described augmented periods, but the disordered contractile activity directly after surgery was followed by a period of quiescence (Baker and Webster, 1968). In the pig, a normal MMC length consists of 70–115 min (Rayner and Wenham, 1986), while only few data describe the immediate effects of surgery on duodenal motility. Thus, the proximal duodenum, as the first part of the small intestine, has a special role to play in the digestive tract. It acts as a reservoir for evacuated gastric chyme, with electrical and mechanical events of the stomach and the duodenum being partially fused. Thus, if surgical manipulations influence duodenal motility, this effect has to be of concern for the postoperative therapy. Accordingly, our results demonstrate that a laparotomy of the upper abdominal wall in conjunction with a proximal duodenotomy and the introduction of a flexible impedance catheter did not significantly influence the length of the MMC cycle or the time periods of the interdigestive phases I–III in pigs.

During phase II, Nguyen et al. (1995) described different transport patterns of chyme, termed bolus transport events (BTE) in conscious humans. The latter events were found in the duodenum using impedancometry. Accordingly, our results show that BTE were detectable during phase II only. This emphasises the role of the BTE as a food-propelling transport event, which could neither be found during the phase of quiescence, named phase I, nor during phase III. In addition, we found that duodenotomy showed no significant influence on the quantity of these bolus transport events.

Intraluminal impedancometry is a novel and validated approach, which promotes measurements of the duodenal motility activity (Imam et al., 2004). Recently, this was validated by comparing the method with manometry and real-time ultrasound. In contrast to manometry, the impedance technique promotes measurements independent of the surrounding pressures. Former investigations using manometry, which probably underestimated gastric motility as low pressure waves (< 10 mm Hg), were excluded from their analysis (Collard and Romagnoli, 2001). Conclusively, impedancometry might be of advantage if 'non-occlusive motility waves' are to be monitored (Savoye-Collet et al., 2003).

Although intestinal function has been investigated in different species, we studied pigs with 32 to 40 kg body weights because previous experience allowed us to use the monitoring comparable to those usually applied in humans. In general, the pig is considered to be a suitable non-primate animal model since it resembles the human situation with regard to eating behaviours, anatomy, and physiology of the gastrointestinal tract (Kararli, 1995). Although eating behaviours and defecation in the evening and during the following night suggest that any inhibitory effects on intestinal motility on the following day can be neglected, the instrumentation might still have influenced the motility measurements. Between the instrumentation and the measurements, all pigs were treated using the pyrazolone derivative metamizol and the nonsteroidal anti-inflammatory drug (NSAID) carprofen for analgesia in a standardised manner. While the motility of the small intestine seemed to be unaffected, gastric emptying was decreased by metamizol in the rat (Rupp et al., 1987). Typical side effects of the long-term application of carprofen are bleeding and ulceration, which can be neglected because of the short-termed model used here. In order to prevent any inhibitory effects on intestinal motility by surgical manipulations in the controls, the impedance catheter was introduced via PEG by endoscopy on the previous day. This was accompanied by the use of a central venous catheter in both groups in order to induce general anaesthesia without any distress in the pig.

In conclusion, our results suggest that right-sided laparotomy combined with duodenotomy does not directly affect the proximal duodenal motility.

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