Recto-anal motility responses in the Göttingen minipig by selective stimulation of the ventral sacral nerve roots

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Abstract

Electrical stimulation of sacral roots for electrodefecation results in simultaneous activation of the rectum and the external anal sphincter. The sphincter contraction hinders evacuation of the rectum. In this study anodal blocking has been used to reduce the activation of the external anal sphincter. Using a tripolar cuff electrode and monophasic rectangular current pulses in 7 acute minipigs experiments the pressure response in the anal canal was reduced more than 80 % in all animals compared to stimulation without blocking. The result confirms previous results from the bladder, in other species, in that selective small fibre activation can be obtained using an anodal block.

Keywords: anodal blocking, sacral ventral nerve roots, external anal sphincter

1. Introduction

In normal individuals, defecation is the result of simultaneous relaxation of striated muscle of the anal sphincter and contraction of smooth muscle of the rectum. Following spinal cord injury control of normal bowel activities is lost. This leads to intractable constipation associated with episodic fecal impaction and overflow incontinence [9]. Bowel management is needed to obtain bowel emptying. Practically this can be obtained by the use of a stool softener and digital stimulation of the rectum by the gloved hand to trigger the defecation reflex [9]. An alternative way to obtain defecation is to activate the rectum using electrical stimulation. In this study we used sacral root stimulation to activate the rectum.

1.1. Previous Work

The Finetech-Brindley sacral root stimulator [2] was initially developed to improve bladder emptying, but as the nerve fibres innervating the distal colon, rectum and anal sphincter are in the same nerve roots as the fibres innervating the lower urinary tract, the stimulator could also be used to induce defecation. However, upon stimulation both the rectum and the anal sphincter contract which hinders bowel emptying [10]. Some patients can defecate using the method of ‘post-stimulus’ defecation but defecation in general is poor. Defecation would improve if the rectum could be activated without activation of the anal sphincter. As the rectum is innervated by small diameter nerve fibers and the anal sphincter is innervated by larger diameter nerve fibers, selective small fiber activation would give the desired result. A number of studies have shown that a selective anodal block [11,12] can be used to obtain selective small nerve fibre activation. The aim of this study was therefore to investigate, in the Göttingen minipig, whether activation of smooth muscles of the rectum without activation of the anal sphincter could be induced by selective stimulation of the ventral sacral nerve roots (S2-S3).

2. Methods and Materials

Surgical procedures

Acute experiments were performed on 7 female Göttingen minipigs, 10-13 months old. The pigs were fasted from the night before the experiment but had free access to water. All procedures were carried out in accordance with the Danish law on care and use of laboratory animals. The pigs were pre-anæsthetised with Ketalar (Ketaminol vet.®, 5 mg/kg im.) and Midazolam (5 mg/kg im.). Anaesthesia was induced by α-chloralose 62.5 mg/kg iv. and maintained with α-chloralose (50 mg/kg/h iv.). The pigs were endotracheally intubated and mechanically ventilated. Blood pressure, gases and ECG were monitored during the experiments. The pigs were placed in a prone position on a thermal mattress to ensure constant body temperature. A laminectomy was performed from S1-S4 and the dura was opened to expose the intradural sacral roots. The roots (S2-S3) were identified by their size and by test stimulation. The
roots were separated in a dorsal and ventral part and a tripolar cuff electrode was placed around the intradural ventral roots, which innervated the anal sphincter. Stimulation responses of the rectum were measured using an impedance planimetry probe. The probe was gently inserted into the rectum with the small bag lying in the high-pressure zone of the anal canal. The pressure in the rectal balloon was set to 5 cm H2O above the resting rectal pressure. The urinary bladder was kept empty to avoid reflex interactions [1,3].

Experimental probe design
Impedance planimetry allows simultaneous measurement of intraluminal pressure and estimation of the cross-sectional area (CSA) of a balloon placed in a tube or hollow organ [4,5]. The CSA is estimated using Ohms law [6,7]. The impedance measuring electrodes were mounted on an 18 cm long probe with an outer diameter of 9 mm (Fig.1). The excitation electrodes (the two outer electrodes) are 12.5 cm apart. The probe had 5 pairs of detection electrodes with a spacing of 2 cm between the pairs and 2 mm between the electrodes of each pair. The excitation electrodes were supplied with an AC current of 0.1 mA at 10 kHz. The probe and electrodes were covered with a flaccid bag (14 cm long) made of 50 µm thick polyurethane. Through several infusion channels the bag could be filled and emptied with saline 0.018 % and a rectal distension pressures could be set by changing the level of a container (Fig. 1). A channel to monitor pressure was also present. The anal bag was made of PVC (4 ml). The bag had 1 infusion channel and 1 channel for measurement of anal pressure (Fig. 1). Records of CSA, rectal- and anal pressures were stored on a computer using the software package Openlab (Gatehouse, Nørresundby, Denmark) [6].

Nerve stimulation
The sacral nerve roots were stimulated using “split-cylinder” tripolar cuff electrodes (cathode flanked by two anodes). They consisted of three 0.5 mm wide circular platinum foil contacts embedded in a tubular insulating sheath of silicone rubber (inner diameter: 1 mm, contact spacing: 2 mm) [8]. The electrodes were connected to a self-made computer stimulator. Monophasic pulses were used for excitation and blocking.

3. Results
Contraction of the EAS was obtained in 4 pigs by stimulation of the S2 root and by stimulation of the S3 root in 3 pigs. In 3 pigs rectal responses were obtained. In 1 pig rectal responses was achieved by stimulation of the S2 ventral root and in 2 pigs by stimulation of the S3 ventral root.

Short duration pulses
In all 7 pigs unilateral stimulation of the S2 or S3 roots with trains of 100 or 200 µs wide pulses at a low as well as high amplitude resulted in a contraction of the EAS. Threshold for activation was 0.02-0.05 mA and full recruitment was ranging between 0.1-0.5 mA. In the 3 pigs where also rectal responses were shown the measurements were performed using CSA. As shown in Fig. 2 and 3 the response varied. Rectum responses started almost at the end of stimulation and continued after stimulation had stopped. Rectal pressure increased in response to stimulation. (Fig. 2). At amplitudes below 0.4 mA no responses from the rectum were noted. For clarity only two of the five measured CSA’s are shown in the figures. The 3 other pairs of detection electrodes showed an increase in CSA, which could also be expected.

Long duration pulses
Using pulse duration of 400-600 µs total anodal blockade of the induced action potentials in the large fibres occurred at amplitude varying from 0.8 to 1.8 mA. In the pigs where also rectal responses were measured the CSA measurements varied. Different from stimulation with short time duration pulses, the
responses started simultaneously with onset of stimulation. Rectal pressure increased in response to stimulation in all 3 animals (Fig. 3). With amplitudes below 0.4 mA no rectal responses were noted. The results from the 3 not shown pairs of detection electrodes were a decrease in CSA at the 2. pair and an increase in CSA at the 3. and the 4. pair, which could also be expected. In Fig. 3 it is shown that selective activation of the rectum with activation of the internal anal sphincter was obtained resulting in a decrease in anal pressure during stimulation. When blocking was obtained without rectal response no change in anal pressure was measured during or after stimulation. The decrease in anal pressure, which is shown here, was not observed.

![Graph](image)

**Fig. 3** Same pig as in Fig. 2. Anal (AP), rectal (RP) pressure and rectal CSA responses to unilateral stimulation of a S2 ventral nerve root. Stimulation parameters: pulse duration 500 µs; 20 Hz; 0.95 mA in 15 s. For clarity only CSA’s from detection electrode (DE) 1 and 5 are shown.

4. **Discussion**

The results of this study demonstrate that selective activation of the rectum, without activation of the anal sphincter when stimulation the sacral roots is feasible using anodal blocking. These results are similar as shown for bladder control. In those studies it was possible to induce activation of the detrusor simultaneous with blocking the sphincter [12]. However, in this study responses from the rectum were only obtained in 3 out of 7 animals. In the other 4 animals rectal responses could not be elicited using the stimulation parameters, which induced stimulation and blocking at the EAS. The explanation might be that the responses from the sphincter and the responses from the rectum were located in separate roots in 5 out of the 7 pigs.

5. **Conclusions**

This study shows that undesirable contraction of the EAS in response to ventral sacral nerve stimulation can be largely reduced. This technique may allow more physiological defecation act for patients with spinal cord injuries.

6. **Acknowledgment**

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**References**