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New Telemetry Device for the Measurement of Gastrointestinal Motility in Rats and Comparison With Standard Equipment

Tobias Meile, Derek Zieker, Alfred Königsrainer, Jörg Glatzle

University Hospital Tübingen, Tübingen, Germany

To perform stress-free recording of gastrointestinal motility in rats with strain gauge transducers, telemetry equipment had to be developed. We developed, programmed, and tested a new telemetry device that records gastrointestinal motility in freely moving rats using strain gauge transducers. The device can collect and transmit data in freely moving rats. Data are received and stored for later analysis with a regular PC. Linear calibration curves were obtained for the strain gauge transducers used. We compared data obtained with the new telemetry device with data gathered with standard equipment and could not find any statistically significant difference. Wired gastric and colonic contraction frequencies were 4.6 ± 0.3 per minute and 1.5 ± 0.3 per minute, whereas telemetric contraction frequencies were 4.4 ± 0.1 per minute and 1.25 ± 0.1 per minute. The new telemetry device is a very useful tool for the measurement of gastrointestinal motility in rats.

Key words: Intestine – Motility – Rat – Strain gauge transducer – Telemetry

Recording of gastrointestinal motility is an important instrument in modern science. Since the year 2000, 981 Medline-listed journal articles on gastrointestinal motility in rats have been published. A wide variety of technical solutions are available for this purpose, but most are very invasive or require large numbers of animals.[1–4] Manometry in rats is technically difficult, and animals need to be fixed during measurements.[5–7] Transit time permits measurement of the whole intestine, but large numbers of animals are needed because animals have to be killed at each time point. Electrophysiology measures gastrointestinal contractions in a very indirect way. The correlation between electromyography and transit is uncertain.[8] Animals need to be restrained in most setups, and measurement is very difficult in live animals. Strain gauge transducers can measure contractions in all parts of the intestine, but when common technology is used, animals need to be fixed and measurement time is

Corresponding author: Tobias Meile, Hoppe Seyler Str. 3, 72076 Tübingen, Germany.
Tel.: +49 (0)7071 29 86611; E-mail: tobias.meile@med.uni-tuebingen.de

Fig. 1 Telemetry device with two channels for the transmission of gastrointestinal motility obtained in rats with strain gauge transducers.

limited. No systems are available for continuous measurement of gastrointestinal motility in freely moving rats. Nevertheless, fixation of the animals might compromise results because of high stress levels.[9] Short measurement times also limit results obtained with methods that require fixation. Our research team used a well-established motility model employing strain gauge transducers.[10,11] We evaluated a telemetric myoelectric system in the small intestine.[2] We have now developed and evaluated a system for continuous measurement of gastrointestinal motility in awake, freely moving rats using telemetric data acquisition combined with strain gauge transducers.

Materials and Methods

Transmitter, responder, and software

We developed a transmitter small enough to be carried by a rat. Up to two strain gauge transducers can be connected to the transmitter. Inside the transmitter, signals are amplified and digitalized. This is done by a small, programmable microcontroller. Data subsequently undergo wireless transmission to the responder, which is connected to a regular PC (Fig. 2). Software installed on the PC decodes, displays, and stores data for later evaluation. The transducer's dimensions are 4.4 × 3.1 × 1.4 cm and it weighs about 18 g, which rats can easily carry. Figure 1 shows the device and its dimensions.

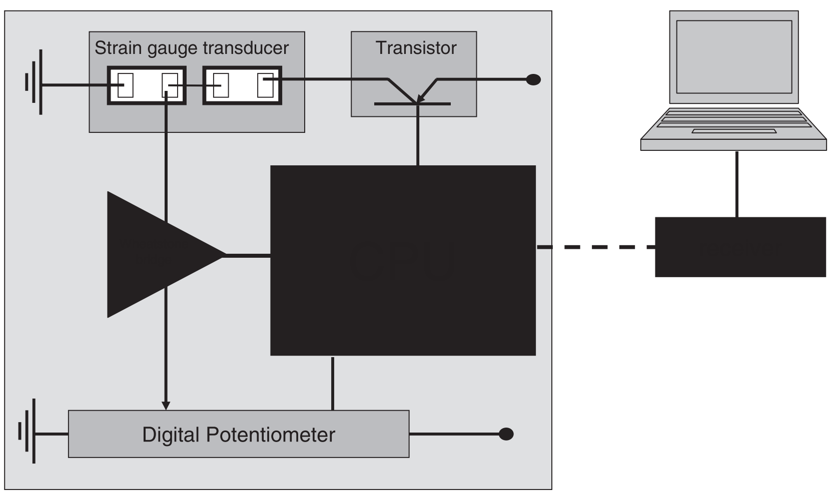

Fig. 2 To reduce power consumption, strain gauge transducers are usually switched off. The transistor switches them on for milliseconds during each measurement cycle. The Wheatstone bridge compares the measured current from the strain gauge transducer and the current obtained from the digital potentiometer, and amplifies the difference by about 1000 times. The resulting current is digitalized in the CPU. Internal software monitors the baseline and adjusts the digital potentiometer. Digital data are than transmitted as a serial sequence via the telemetry unit. A standard PC can be used to receive and store generated data.

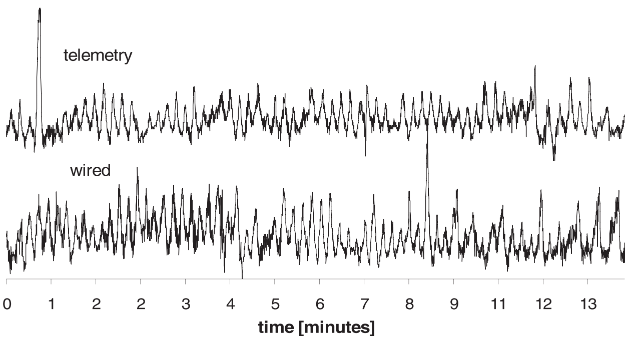

Fig. 3 Gastric motility measured with strain gauge transducers in rats. The upper curve shows telemetric data; the lower curve, standard wired data.

It runs on 3-V rechargeable batteries that can hold a charge for about 6 hours and can be easily replaced during the experiment. Nonrechargeable batteries that can hold a charge for up to 12 hours are available, if needed. Sampling rate is 5 Hz. Figures 6 to 9 show how to build the device including circuit diagram, circuit layout, and mounting diagram.

Calibration curve

Strain gauge transducers (n = 5) designed for gastric, small intestinal, or colonic motility measurement in rats were placed in a micrometer screw and slowly squeezed. Change in diameter and measured output signal were correlated. This allowed us to calculate a calibration curve for the whole system.

Animals

Male Sprague-Dawley rats (Charles River, Kisslegg, Germany) weighing 450 to 550 g were housed under conditions of controlled temperature (22°C ± 1°C) and illumination (lights on 6 AM to 6

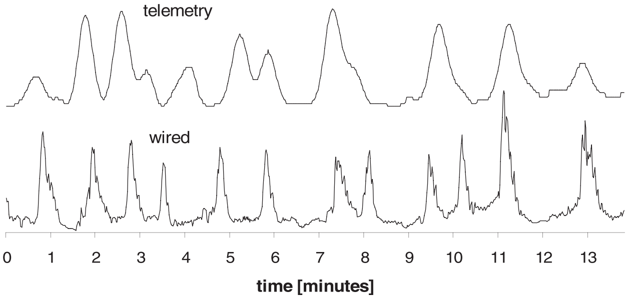

Fig. 4 Colonic motility measured with strain gauge transducers in rats. The upper curve shows telemetric data; the lower curve, standard wired data.

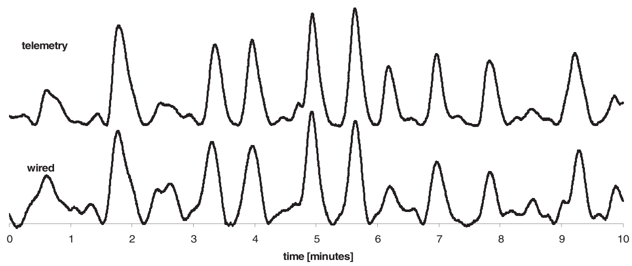

Fig. 5 Colonic motility recorded simultaneously with wired and telemetric equipment. The upper curve shows telemetric data; the lower curve, standard wired data.

PM). The research protocol was approved by the local animal research committee (approval number C04/03), and the institutional guidelines for the care and use of laboratory animals were followed throughout the study. Rats were fasted for 16 hours before experiments and were given free access to water.

Comparison between wired and telemetric systems

Strain gauge transducers were produced as previously described.[12] Rats were anesthetized with an intraperitoneal injection of ketamine (100 mg/kg, Ketanest, Parke Davis, Berlin, Germany) and xylazine (15 mg/kg, Rompun, Bayer, Leverkusen, Germany). The gastrointestinal tract was exposed by midline laparotomy, and strain gauge transducers were sutured to the gastric corpus and the right colonic flexure parallel to the circular muscle layer with a 7/0 thread (Ethilon, Ethicon, Norderstedt, Germany). Wires were brought to the exterior between the scapulae and stored in a backpack. On day 2 of the experiment, transducers were placed in the backpack and connected to the wires. Rats could easily carry the transducer and did not show any sign of discomfort. To generate equal conditions, rats were placed in Bolman cages and connected either to the well-established wired Wheatstone bridge (2100 System, Measurements Group, Raleigh, North Carolina) or to the new telemetry transmitter. After 1 hour connections were changed. Animals connected to the wired system were switched to the telemetry transmitter and *vice versa*. The sequence of the experiment was determined at random.

Analysis of gastrointestinal motility

Motility recordings were analyzed with dedicated software (Intestinal Data Acquisition and Analysis,

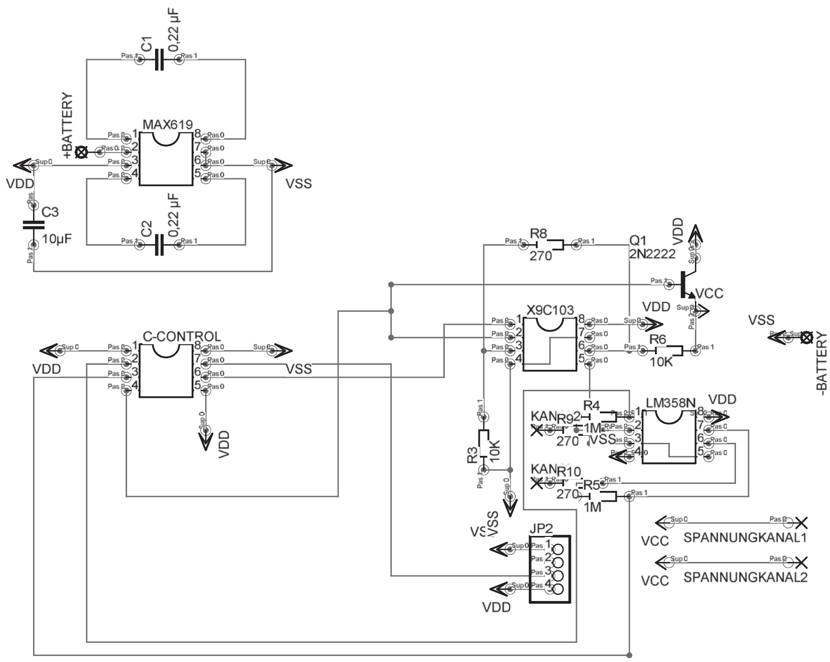

Fig. 6 Circuit diagram.

version 3.40.15, Standard Instruments, Karlsruhe, Germany) that calculated the contraction frequency and the mean contraction amplitude (n = 4).

Simultaneous recording with both systems

In order to simultaneously record gastrointestinal motility with the wired and the telemetric systems, both have to share the same electric ground. This called for some electric manipulations. Strain gauge transducers were connected to the telemetry transmitter and the wired Wheatstone bridge at the same time. Data for optical evaluation were displayed on the same graph.

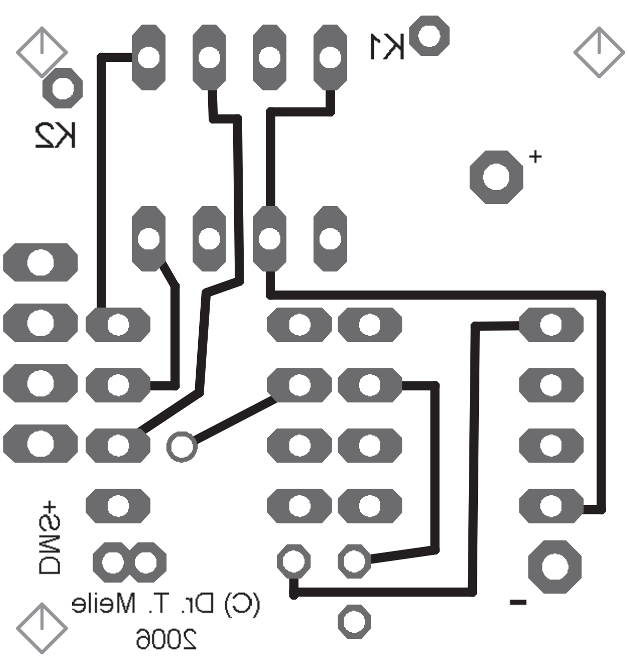

Fig. 7 Circuit layout front side.

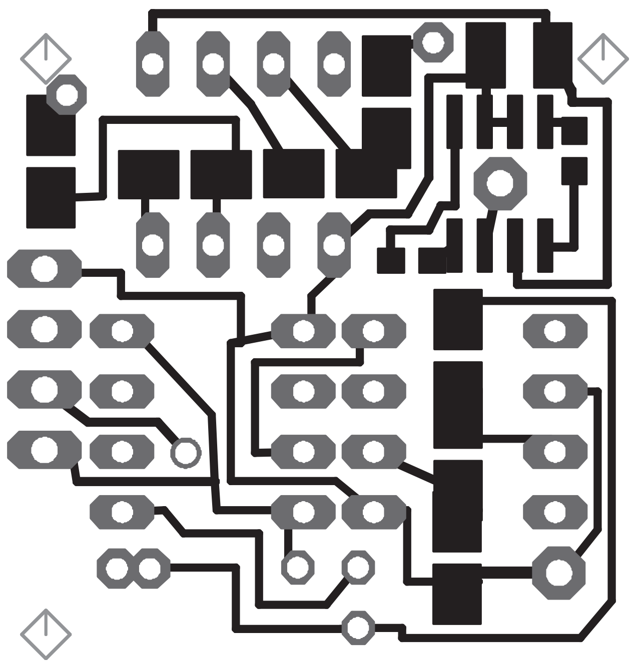

Fig. 8 Circuit layout back side.

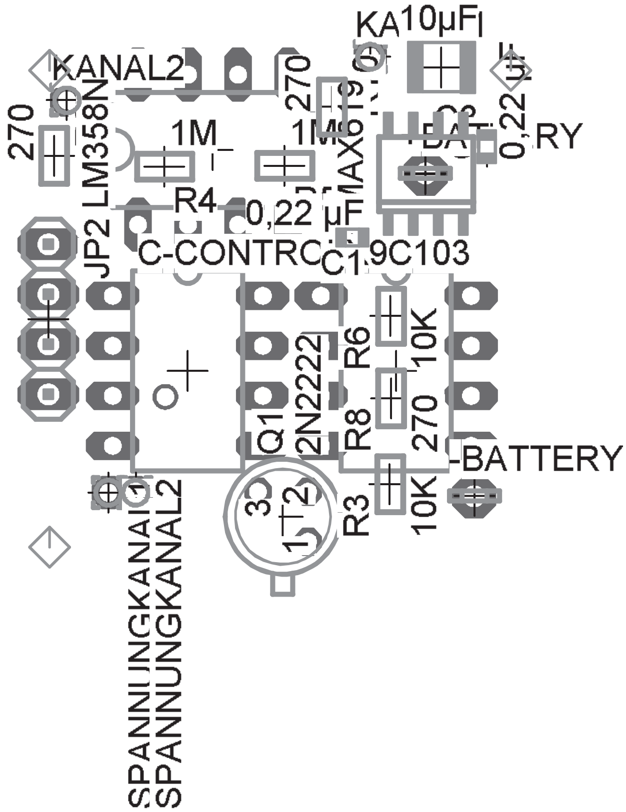

Fig. 9 Mounting diagram.

Statistics

All data are given as mean ± SEM. The significance of difference between the telemetric and wired systems was determined with an unpaired two-sided *t* test. $P < 0.05$ was considered statistically significant. To evaluate the calibration curves we used the Pearson correlation. Coefficient of determination is given as R^2. $P < 0.05$ was considered statistically significant.

Results

Calibration curve

Linear calibration curves were obtained in all cases. Inclination of obtained calibration data was 1690 per millimeter. Coefficient of determination was $R^2 = 0.90$ with $P < 0.05$.

Comparison of wired and telemetric systems

The wired and telemetric systems generated data typical for gastric and colonic motility as shown in Figs. 3 and 4. The wired gastric contraction frequency was 4.6 ± 0.3 per minute, and the telemetric gastric contraction frequency was 4.4 ± 0.1 per minute. Colonic contraction frequency was 1.5 ± 0.3 per minute (wired) and 1.25 ± 0.1 per minute (telemetry). Gastric mean contraction amplitude was 36 ± 1.7 µm (wired) and 31 ± 1.7 µm (telemetry), whereas colonic wired mean contraction amplitude was 24 ± 1.7 µm, and telemetric mean colonic contraction amplitude was 27 ± 3.6 µm. All differences were not statistically significant.

Simultaneous recording with wired and telemetric systems

Wired and telemetrically recorded data are identical.

Discussion

Transportable data loggers for motility recording that can store large quantities of digital signals have been available since 1990. These devices can be used to record gastrointestinal motility in large animals, like pigs or dogs, for prolonged periods of time.[13,14] However, they are too big to be used in small animals like rats. For continuous recording in rats, the animals have to be connected to the recording equipment by wires, thus necessitating restraint cages.[12] Increasing recording time causes stress, which can influence results because stress is known to alter gastrointestinal motility.[9] Ideally, recording should be stress-free for animals, and ethical objections due to prolonged recording periods in restraint cages should be avoided.

A telemetric system for recording colonic motility with solid-state pressure transducers was recently described in Yucatan minipigs.[15] The investigators recorded colonic pressure for up to 144 hours under unrestrained conditions.

We present here a telemetric system that allows the gastrointestinal motility of the rat intestine to be recorded in freely moving rats. This makes long-term, stress-free recording of rat gastrointestinal motility possible. There is no difference in the data obtained with wired strain gauge transducers and telemetrically obtained data. Furthermore, we also describe a possibility for calibrating strain gauge transducers.

Conclusion

Our telemetry system can be used to measure gastrointestinal motility in rats. The data obtained with our system are as valid as the data obtained with wired systems. Our telemetry system provides a good and easy means of measuring gastrointestinal motility in freely moving rats and eliminates the need for restraint cages. Long-term measurement is also possible.

Acknowledgments

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