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Gastrointestinal Radiological Investigations with a New Pump Device: Experimental and Clinical Experiences

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Abstract

In an earlier paper (1) a new pump device for medical applications was described. This enabled a continuous flow of saline, barium contrast agent and gases. We now report further study of this device: The use of gases was experimentally studied to give a basis for use in CT-colonography. We also report experiences from injection of barium contrast agent via a naso-duodenal tube for radiological investigation of the small intestine in patients with gastrointestinal suffering. The radiation exposure to the x-ray staff was reduced. The investigation procedure was standardised and shortened.

Introduction

Gases are used as a contrast agent when studying the colon by computer tomography. Gases are highly compressible at low pressures. The exact compressibility factor is depending on what type of gas we are using and at what pressure level we are working. This effect makes all volume measurements of gas somewhat complicated and it might be confusing that the measured volume is not constant. If the pressure goes up the volume decreases and vice versa. Beside volume data we must therefore consider at least two pressures (at the position where the meter is installed and at the "effective" point where the gas shall be used). Beside the volume expansion of the gas itself, most measuring equipment is also sensitive (and related) to operational pressure. This means that the measuring instrument in general must be designed for a specific working pressure. Variations in working pressure will result in measuring errors. With this in mind a special test method was created to simulate real use of the instrument, trying to copy the gas flow during a gastrointestinal radiological investigation.

Methods

The pump device *Octapump Injection System 1* (OIS-1) is governed by a 32 bit microprocessor, which performs all tasks, charging batteries, user interface, mo-

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tor steering, bubble control and safety checks. Program environment is native to the processor, eliminating computer viruses. The pump is charged from a separate charger monitored by the processor. The user interface consists of 7 keys, 4 of them which are situated under the colour LCD TFT read out. The function of the keys is described on the display. The motor is a three phase brushless servo type, which can not run too fast or uncontrolled. The bubble detector uses light at 45 degrees angle through the output part of the Dosin®, giving a static detection of air or air bubbles and not just the bent shape of bubble front. There is ample storage for user specified injecting routines. These are kept in flash memory and retained after power has been broken. A PIN code allows only authorized user.

Gas measurement experimental setup

The pump device (1), (Dosin® and *Octapump Injection System 1*), was tested volumetrically in a set up according to the figure below. A measuring glass was half filled with water. The air coming from the injection system was connected to a plastic bag, placed below the water surface inside the measuring glass. Air volume was then measured by means of the changing water level. At atmospheric inlet pressure (101 kPa) the inlet tube ("A" in figure 1) was just left open to the room. With higher inlet pressures "A" was connected to compressed air via a pressure regulator.

No volumes/results were recalculated due to changing air pressure. Only displayed data were used, and no other special equipment or software was used. Room, air and water temperatures during all tests were 21 ±1 ºC.

Radiological procedure

The gastrointestinal tubes were connected to the Dosin® (1) in the pump device and the barium contrast container through a plastic tube with luer lock (kit from DX Plastic AB, Bredaryd, Sweden) connected to the inlet of the Dosin®. 300 mL of 60 % suspension of barium contrast were injected for 10–15 minutes during surpervision upon the monitor in the adjacent manouver room. After the the preprogrammed injection was completed the pump stopped.

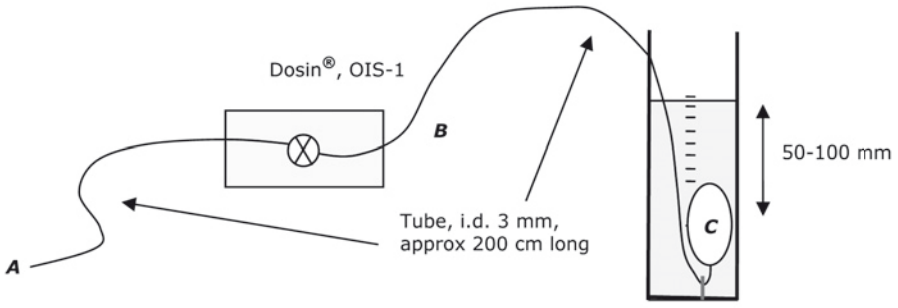

Fig 1. The air enters the tube at A and the Dosin® which is attached to the motor unit OIS-1pumps then the air through the Tube B to the plastic bag C which is placed in the water in a measuring glass.

The device was used for injection in 38 patients during radiological examination of the small intestine, when using barium.

Patients

During the period 2006-01-19–2006-05-31 38 patients, 13 men and 25 women, were investigated with enteroclysis using the above described pump device. The patients were 21–87 years old (mean 54, SD 19). The main causes for referral were abdominal pain, diarrhoea, blood in faeces and unexplained anaemia. In 6 of the patients the diagnosis Crohn´s disease was already known, 5 of which had undergone one or several resections of the small intestine.

Results

Experimental

The results are displayed in Table 1.All results are presented as the average value from 3 individual measurements. "Sample no." refers to the individual Dosin® that was used in the test. Flow rate and inlet pressure were measured and controlled during each test.

Measurement error (E) is defined by $E = \frac{indicated\ volume - delivered\ volume}{delivered\ volume} \times 100$ where indicated volume is displayed on the device and the delivered volume is measured by water displacement. I.e. a positive measurement error indicates too small a dose.

The stability of the results is indicated by the range (R), the difference between the largest and smallest error. $R = E_{max} - E_{min}$.

No compensation was made due to air volume changes (pressure variation / varying water level at "C" in figure 1, estimated to less than 1% in volume). The total uncertainty in the measurement procedure, i.e. the determination of the measurement error, is estimated to be less than ±5 % of the specified delivered volume error.

Radiological

In one of the patients, an 87 year old woman the investigation had to be interrupted before the contrast agent had reached colon. In all other patients the investigation was technically sufficient.

In 7 patients there were radiological signs of inflammatory bowel disease such as lumen narrowing or dilatation, wall stiffness or mucosal cobble-stone pattern. In 6 of these patients the diagnosis Crohn´s disease was already known. In two cases it was possible to compare with previous enteroclysis examinations, in one of these there was a clear progress of the disease, in the other the state was unchanged.

Table 1.Sample no refers to the individual Dosin® that was used in the test. Sample 10 was used for a flow rate of 3600 mL/s at two inlet pressure. Sample 11 was used for increasing flow rates but a constant pressure. Flow rate was measured in mL/h through the Dosin® and the pressure was given in kPa a.

Sample no.	Flow rate (mL/h)	Inlet pressure (kPa a)	Error (E) (%)	Range (R) (%)
5	3 600	101	+ 2	< 1
10	3 600	101	+ 6	< 1
10	3 600	101 *	+ 6	< 1
10	3 600	124	- 27	< 6
10	3 600	143	- 44	< 1
11	1 800	101	+ 1	< 2
11	2 400	101	+ 1	< 2
11	3 600	101	+ 1	< 2
11	4 200	101	+ 4	< 2

*) With increased outlet pressure (a reducer installed at “B” on the tubing in figure 1)

In 3 patients we found a suspected small bowel tumour, which had to be further investigated.

In 4 patients there were one or several small bowel diverticula, which might be a cause of the patients´ symptoms. The diverticula were located in the duodenum or proximal jejunum.

In 24 patients there were no pathological findings. Five of these patients had earlier undergone surgery for Crohn`s disease, in most cases an ileo-caekal resection.

Discussion

The measuring principle of this pump device is insensitive to outlet pressure, which makes it possible to use the device regardless of outlet pressure. Of course, it may still be necessary to compensate for the compression of the gas itself. The experiments indicate that the gas supply (pump inlet) must be controlled to atmospheric pressure to avoid measuring errors. When using pressure about 100 kPa the errors were small with small variations.

The patients represented a common clinical variation of disease. They suffered no side effects of our procedure, which was time-saving and reduced the radiation dose to the x-ray staff.

The pump can be used for both gas and fluid-like contrast agents suspensions. Thus it may have applications in common clinical procedures since it can handle different fluids as gases or barium contrast solutions.

References

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