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New Hysteroscopy Pump to Monitor Real-Time Rate of Fluid Intravasation

Atul Kumar, MS*, and Alka Kumar, MS

From the Hysteroscopic Surgery Division, Women's Health Centre, Jaipur, India (both authors).

ABSTRACT This article describes the benefit of monitoring the intravasation rate in addition to the conventional measurement of fluid deficit in hysteroscopic surgical procedures. The intravasation rate is the rate, in milliliters per minute, at which fluid enters the systemic circulation, whereas fluid deficit is the amount of irrigation fluid, in milliliters, already absorbed by the patient. To determine the intravasation rate, a manually operated intravasation monitoring pump was constructed, with which one of us (Dr. Atul Kumar) performed 966 hysteroscopic procedures from May 1993 to February 2010. Because the intravasation rate had to be manually calculated by an assistant, it was decided to replace the assistant with a controller to monitor intravasation rate. The surgical experience gathered from the manually operated pump was used to develop algorithms for the controller. The controller-operated intravasation monitoring pump was constructed, with which 41 hysteroscopic procedures were performed from March 2010 to August 2011. In hysteroscopic procedures, this pump simultaneously displays the real-time intravasation rate and the fluid deficit on an LCD screen. Journal of Minimally Invasive Gynecology (2012) 19, 369–375 © 2012 AAGL. All rights reserved.

Keywords: Cavity flow rate; Flow rate; Fluid deficit; Hysteroscopy; Intravasation rate; Pressure; Pump; Real time

Hysteroscopy is a useful technique for diagnosis and treatment of various gynecologic diseases. However, fluid intravasation [1,2] is a major associated complication that can cause morbidity [3] and death [4,5]. Intravasation is generally described as a process by which the pressurized irrigation fluid enters the systemic circulation through the cut ends of the traumatized blood vessels, and the flow rate at which this fluid enters the blood vessels is the intravasation rate, in milliliters per minute. This complication cannot be avoided in any hysteroscopic procedure, in particular if deep tissue with large blood vessels is accidentally traumatized. Hence, meticulous fluid monitoring [6] is recommended in all hysteroscopic procedures.

The intravasation rate is influenced by several factors, e.g., uterine cavity pressure [1,7] and hemostatic mechanisms [8] in the vicinity of the traumatized blood vessels. However, such mechanical and physiologic mechanisms, being dynamic, tend to vary during surgery, thereby influencing the intravasation rate. Current methods of fluid monitoring do not include the intravasation rate, and rely on measuring the fluid deficit. Fluid deficit is the total amount of fluid, in milliliters, already absorbed by the patient, and is calculated by subtracting the amount of fluid recovered in the fluid outflow reservoir from the fluid that was instilled into the uterine cavity.

Intravasation can occur suddenly and without warning [1], and it cannot be predicted when the intravasation rate increases or decreases. If the intravasation rate begins to increase only a few minutes or seconds before the fluid deficit is measured, a normal fluid deficit measurement could be logically achieved despite the existing high intravasation rate. This normal fluid deficit value does not prompt the surgeon to reduce cavity pressure, and, hence, the fluid deficit continues to rise. If the intravasation rate is known, the uterine cavity pressure could be

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Corresponding author: Dr. Atul Kumar, MS, Hysteroscopic Surgery Division, Women's Health Centre, 11 Rathore Nagar, Queens Rd., Viashali Nagar, Jaipur, Rajasthan 302021, India.
E-mail: alkaatul@sancharnet.in

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Table 1

Differences between intravasation rate and fluid deficit

Intravasation rate (mL/min)	Fluid deficit (mL)
Relates to fluid flow rate	Relates to fluid volume
Reflects the rate at which fluid is still entering the patient	Reflects the total volume of fluid that entered into the patient in the initial phase of surgery
Real-time event	Not a real-time event
Establishes active intravasation	Does not establish active intravasation

reduced despite a normal fluid deficit value. Thus, a low fluid deficit does not always rule out the presence of a dangerous intravasation. Similarly, a high fluid deficit does not always establish that intravasation is still active, because an initially high intravasation rate could decrease as the surgery progresses. If the intravasation rate is known, the pressure may not be reduced despite an elevated fluid deficit value. Remedial measures are not totally risk free. Reducing the cavity pressure could compromise visualization, and hastening the procedure increases the risk of perforation or incomplete tissue destruction; hence, remedial measures must be justified. We believe that it could be beneficial to monitor both the intravasation rate and the conventional fluid deficit value. The difference between intravasation rate and fluid deficit are given in Table 1. The present study describes a technique for determination of the real-time fluid intravasation rate in hysteroscopy.

Development of Intravasation Rate Monitoring Pump

The technology to monitor the real-time rate of fluid intravasation during hysteroscopy was conceptualized 18 years ago, and a manually operated intravasation monitoring pump prototype was constructed (Fig. 1). Our institutional ethics committee approved the research, and all patients gave informed consent. From May 1993 to February 2010, one of us (Dr. Atul Kumar) successfully performed 966 hysteroscopic procedures using the manually operated pump. Because the intravasation rate had to be manually calculated by an assistant, it was decided to replace the assistant with a controller. The surgical experience gathered from using the manually operated pump was used to develop algorithms for the controller. A controller-operated intravasation monitoring pump was constructed by attaching the controller to the existing manually operated pump. From March 2010 to August 2011, 41 hysteroscopic procedures were performed using the controller-operated pump (Fig. 2). Before surgical use, both pumps underwent strict laboratory testing to verify the accuracy of parameters such as pressure, flow rates, real-time fluid intravasation rate in milliliters per minute (R3), and fluid deficit. In the present study, minimal fluid that escaped into the abdominal cavity through patent fallopian tubes was categorized as intravasation.

Fig. 1

Manually operated intravasation monitoring pump.

Description of Intravasation Rate Monitoring Pump

Apart from the controller, the manually operated and controller-operated pumps share a common structural design (Figs. 3 and 4). Both pumps basically comprise an inflow pump and an outflow peristaltic pump, on the inflow and outflow sides of the uterine cavity, respectively; a bypass tube housing a constriction site between the inflow tube and the fluid supply tube; and a pressure sensor near the outlet end of the inflow pump. The inner diameter of the constriction site is initially determined via empirical means, and is not changed thereafter. In addition, the controller-operated pump includes a controller, and is schematically represented as follows: controller-operated pump = manually operated pump + controller.

Both pumps use a common basic equation to determine the intravasation rate: $KP = (R1 - R2 - R3)^2$, where K is a mathematical constant; P is the pressure, in millimeters

Fig. 2

Controller-operated intravasation monitoring pump.