

# Calculating Intraoperative Fluid Deficit to Prevent Abdominal Compartment Syndrome in Hip Arthroscopy



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**Abstract:** Abdominal compartment syndrome (ACS) is a rare but potentially fatal complication that can occur during hip arthroscopy. This usually occurs as a result of arthroscopic fluid passing into the retroperitoneal space through the psoas tunnel. From the retroperitoneal space, the fluid can then enter the intraperitoneal space through defects in the peritoneum. Previous studies have identified female sex, iliopsoas tenotomy, pump pressure, and operative time as potential risk factors for fluid extravasation. We present a method to measure intraoperative fluid deficit during hip arthroscopy to alert surgeons to possible ACS. Our proposed technique requires diligent intraoperative monitoring of fluid output through various suction devices, including suction canisters, puddle vacuums, and suction mats. The difference is then calculated from the fluid intake from the arthroscopic fluid bags. If the difference is greater than 1500 mL, then the anesthesiologist and circulating nurse are instructed to examine the abdomen for distension every 15 minutes. This, combined with other common symptoms such as hypotension and hypothermia, should alert the surgical team to the development of ACS. Despite limitations to this technique, this approach offers an objective method to calculate intra-abdominal fluid extravasation.

Arthroscopic hip surgery has become a popular alternative to open hip surgery, resulting in lower complication rates, quicker return to activities, and improved clinical outcomes.<sup>1,2</sup> As indications expand,

hip arthroscopy is being increasingly performed for many different intra- and extra-articular pathologies.<sup>3</sup> Despite the overall lower rate of complications compared to open surgery, there are still many complications that can arise during hip arthroscopy, including intra-abdominal fluid extravasation (IAFE).<sup>3,4</sup> Previous studies have reported incidence rates of IAFE to be between 0.16%<sup>5</sup> and 16%.<sup>4</sup> Although the exact cause of IAFE is case dependent, factors that have been found to contribute to increased risk are increased pump pressure, concomitant iliopsoas tenotomy, surgeon experience, and prolonged surgical time.<sup>4,6-9</sup>

IAFE during arthroscopic hip surgery directly increases intra-abdominal pressure, resulting in intra-abdominal hypertension (IAH). IAH is defined as sustained levels of intra-arterial pressure greater than 12 mm Hg.<sup>10-12</sup> Left untreated, this can lead to abdominal compartment syndrome (ACS), cardiac arrest, hypothermia, organ failure, and death.<sup>3-7,13</sup> ACS, defined as increased intra-arterial pressure above 20 mm Hg, can result in acute organ dysfunction.<sup>12</sup> Early detection and management of IAH and ACS has shown to result improvement in organ function, reduced patients' postoperative pain levels, and increased patient survival.<sup>4,14</sup> Signs of ACS include

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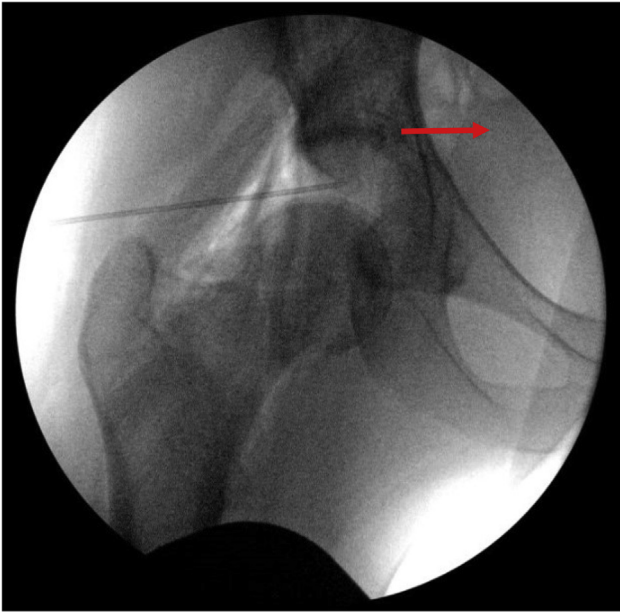
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**Fig 1.** Fluoroscopic image showing an anteroposterior image of the right hip during the initial air arthrogram. This image shows appropriate air within the joint with subtle evidence of air tracking up into the iliopsoas sheath. Air within the iliopsoas sheath presents with lucency proximal to the superior pubic ramus within the inner pelvis, and it represents direct communication between the hip joint and retroperitoneal space. *Red arrow* points at location of air tracking into iliopsoas sheath.

abdominal distension, shortness of breath, hypotension, reduced body temperature, unresponsiveness, and abdominal pain.<sup>14</sup> Some of the pathophysiological considerations include decreased blood flow to intraperitoneal and retroperitoneal organs, oliguria, reduced venous return to the heart, and respiratory insufficiency.<sup>15</sup>

Various studies have suggested ways to detect and treat IAFE during hip arthroscopy to prevent significant harm to the patient. Although ACS remains uncommon, multiple case reports have noted noticeable abdominal distension after surgery, indicating IAFE.<sup>10,11</sup> According to 1 study, IAFE can be diagnosed early with point-of-care ultrasound scanning (POCUS) using the focused assessment with sonography for trauma examination for early detection.<sup>4</sup> Another study suggested the use of transparent drapes over the patient's abdomen to detect abdominal distension during surgery.<sup>16</sup>

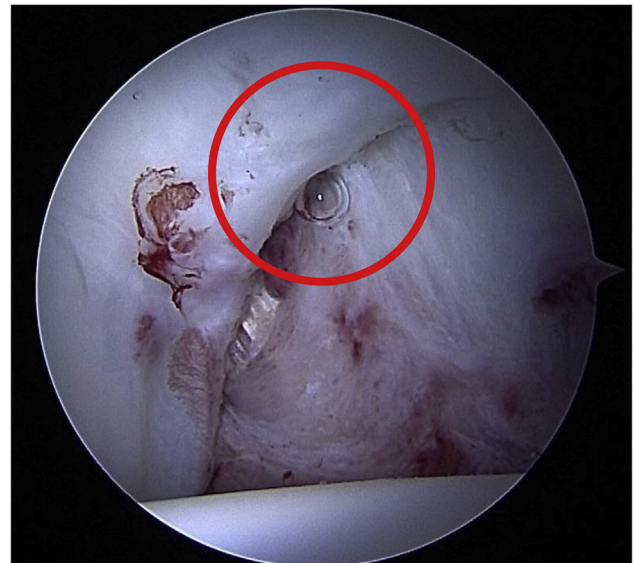
Our study aims at detecting arthroscopic irrigation fluid discrepancy between the input and output flow. Through careful examination and communication between the anesthesiologist and surgeon, the fluid discrepancy is calculated between the volume of fluid entering the patient and the volume of fluid captured in the reservoir. This will allow us to measure approximately how much fluid is being extravasated into the abdominal cavity.

## Surgical Technique

Our proposed technique begins after the patient arrives into the operating room ([Video 1](#)). Once the patient has been appropriately positioned on either a post or post-less traction table in the Trendelenburg position, we start with the initial air arthrogram. We observe for any air tracking up the psoas muscle at this step ([Fig 1](#)), because this may indicate an anatomic abnormality leading to direct communication between the retroperitoneal space and the intraarticular hip joint ([Fig 2](#)). This should alert the surgeon that this patient may be at a higher risk for IAFE.

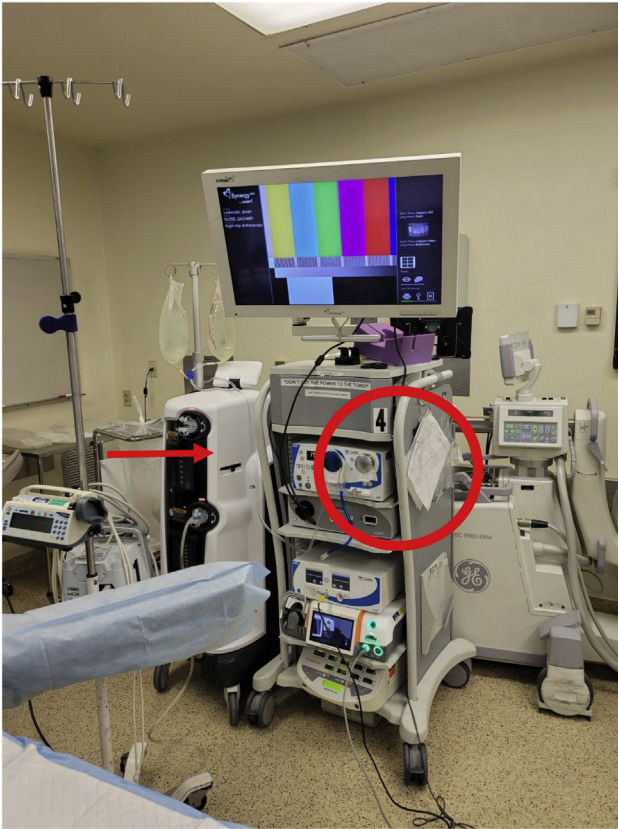
Once the air arthrogram has been completed, we begin with the rest of the operating room set-up. The patient is draped with clear drapes to allow for the surgeon to directly observe any acute changes to the abdomen. Normal saline with epinephrine added to the first two 3L bags is used for the arthroscopic fluid. Fluid administration and pressure is provided with the Conmed 24k (Largo, FL) pump with the Eco-Flow tubing attached to our Conmed arthroscope ([Fig 3](#)). The egress is obtained from multiple sources. Suction is provided by the Stryker Neptune 3, and it is attached to the electrocautery wand, shaver, and arthroscope. Finally, there are also puddle vacuum devices and suction mats on the ground that are directly attached to the Neptune ([Fig 4](#)).

At our institution, there is dedicated circulating staff that are responsible for monitoring the fluid deficit



**Fig 2.** Intraarticular arthroscopic image viewed from the anterolateral portal in the supine position of a right hip showing an anatomic abnormality (red circle) within the iliopsoas tendon. This defect communicates directly with the retroperitoneal space of the abdomen, which can then lead to fluid extravasation into the intraperitoneal space of the abdomen.





**Fig 3.** Operating room set up showing a Conmed 24k (Largo, FL) pump with the Eco-Flow tubing attached to a Conmed arthroscope (red circle). The fluid is collected from multiple sources with suction provided by the Stryker Neptune 3 (red arrow).

counts every 15 minutes. Fluid deficit is measured by subtracting the amount of fluid suctioned during the procedure from the amount of arthroscopic fluid used. At the 15-minute interval, the dedicated circulating nurse will take note of the fluid level in the saline bag and will begin inspection of the surrounding procedural areas for remaining free fluid that may have been left on the drapes or fallen onto the floor. Any free fluid found will be noted to the staff or surgeon for appropriate suction. Net deficiency will then be recorded. Any net deficiency over 1500 mL will trigger the circulating nurse to begin serial abdominal examinations to evaluate for rigidity or distension. These examinations are continued every 15 minutes until the case has been completed.

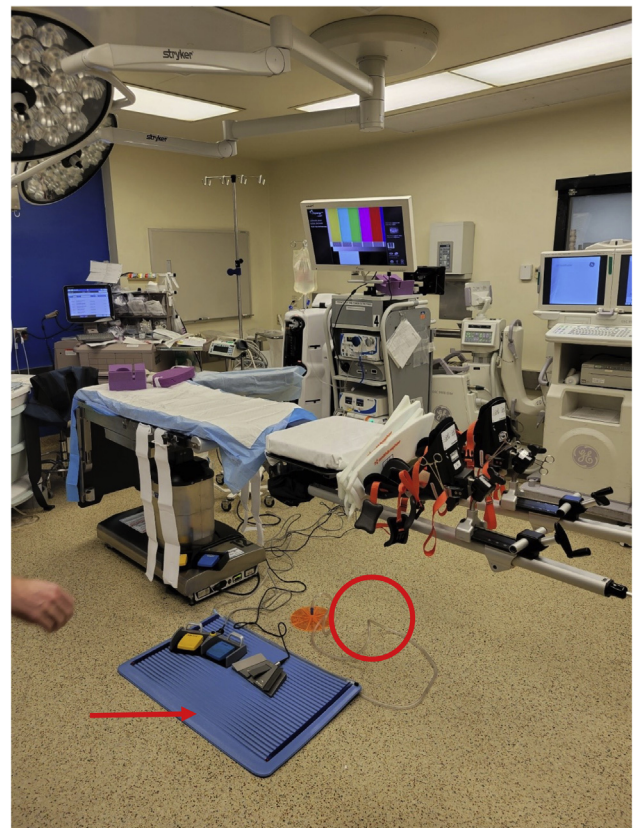
The anesthesiologist is of paramount importance in the evaluation for symptomatic IAFE. The earliest and most sensitive finding of IAFE during surgery was found to be rising peak inspiratory pressures above 20 cm H<sub>2</sub>O.<sup>3</sup> The anesthesiologist is also alerted to watch for any signs of hypothermia or metabolic acidosis, because these have been found to be early symptoms of ACS.<sup>12</sup> Any changes in ventilation requirements, acidosis, or

signs of hypothermia are immediately communicated to the surgeon (Table 1).

All of these measures are continued throughout the entire case, especially once the traction has been released. The ligamentotaxis provided by the traction may actually offer a protective effect by preventing fluid from escaping through the psoas tunnel. Once this tension has been released, it becomes easier for fluid to travel through any potential defects.

## Discussion

As hip arthroscopy becomes more prevalent, the many complications that are associated with this risky procedure must become more clearly defined. Although many of these are minor or reversible, abdominal compartment syndrome is one that has documented risks for mortality. During hip arthroscopy, this usually occurs as a result of arthroscopic fluid passing into the retroperitoneal space through the psoas tunnel. From the retroperitoneal space, the fluid can then enter the intraperitoneal space through defects in the peritoneum. Previous studies have identified female sex, iliopsoas tenotomy, pump pressure, and operative time as potential risk factors for fluid extravasation.<sup>5</sup> Abdominal compartment syndrome can be considered



**Fig 4.** Operating room set up showing puddle vacuum devices (red circle) and suction mats (red arrow) to collect any fluid that falls on the ground.

**Table 1.** How to Assess for IAFE

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Understand risk factors, including iliopsoas tenotomy, operative time, and pump pressure.
Use clear drapes.
Obtain baseline abdominal examination.
Look for air tracking into pelvis during initial air arthrogram.
Anesthesia to watch for hypotension and reduced body temperature.
Circulating nurse to perform serial abdominal exams.
Maintain strict fluid monitoring with precise fluid deficits calculated every 15 minutes.
Observe for increasing abdominal pain after surgery.

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IAFE, intrabdominal fluid extravasation.

a “never event” because of the significant morbidity associated with it, and it is important that every surgeon remain vigilant and aware of the risk for it. This becomes even more vital when recent studies have shown surgeon perception about intraabdominal fluid extravasation to be as low as 0.16%, compared to an incidence as high as 31.1% when intraabdominal ultrasound scanning is used during surgery.<sup>5,8</sup>

Several methods have been proposed to detect the presence of intraabdominal fluid extravasation. Close inspection of the preoperative magnetic resonance image for anatomical variants, particularly between the iliopsoas bursa and hip joint capsule, should alert the surgeon and anesthesiologist for high-risk patients.<sup>17</sup> Clear drapes can be used to allow the surgeon to observe real-time abdominal distension.<sup>18</sup> However, if fluid gradually leaks into the abdomen throughout the surgical period, it may become difficult to easily detect distension of the abdomen. As mentioned above, the anesthesiologist can also look for early signs of abdominal compartment syndrome, such as severe obstructive shock.<sup>19</sup> In addition to clinical symptoms, intraoperative monitoring using point-of-care ultrasound testing has also been proposed.<sup>4,12</sup>

Despite all these previously mentioned methods, the proposed technique in this article of measuring overall fluid deficit offers several distinct advantages. First, it is simple enough that it can be performed at any institution because it does not require any special equipment for measuring fluid loss. Ultrasound scanning is very technician dependent, and it only detects fluid in the intraperitoneal space. Although anatomic variants may exist that allow fluid to travel from the hip to the intraperitoneal space, the more likely path is via the retroperitoneal space. Second, operative time has been shown to be a risk factor for development of abdominal compartment syndrome. This gives the surgeon a direct method to measure potential IAFE versus indirectly observing operative time. Third, this calculation provides real-time, intraoperative, objective analysis for the surgeon. This is in contrast to other methods, which can be subjective (serial abdominal examinations) or time consuming (point-of-care ultrasound scanning).

Finally, in contrast to ultrasound scanning, this technique allows for fluid deficit measurement with the patient in any position, including the prone position.

This technique is not without its limitations (Table 2). The arthroscopic fluid lost on the ground goes into the Neptune suctioning device through a puddle vacuum and a suction mat. Although this may capture most of the fluid on the ground, some of it still remains unmeasured because of the inefficiencies of the suctioning devices. There is also no direct evidence of correlation between the fluid deficit calculation and ACS. Although we can assume that the calculated fluid deficit is entering into the abdominal cavity, there is no objective measurement with ultrasound scanning for confirmation. Also, given how uncommon ACS is, there is no clinical correlation to actual cases of ACS. Finally, the proposed fluid deficit threshold of 1500 mL in our technique is based entirely on anecdotal evidence of abdominal distension and postoperative clinical symptoms; however, more recent data suggest that the volume necessary for symptomatic IAFE is greater than 2 L.<sup>20</sup>

Future studies should look at the correlation of the proposed fluid deficit calculation with abdominal ultrasound measurements. They should also look to correlate any statistically significant changes in fluid deficit with patients that have air tracking up the psoas on air arthrogram. Given the rarity of abdominal compartment syndrome, large clinical trials should be performed to calculate an appropriate fluid deficit threshold associated with the onset of abdominal compartment syndrome. Several other risk factors should be investigated as well, including post-less traction, degree of Trendelenburg positioning, and fluid pump type. Patient risk factors should be further investigated as well. Previous abdominal surgery can lead to less peritoneal cavity compliance, and chronic

**Table 2.** Pearls and Pitfalls

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<b>Pearls</b>
The initial air arthrogram can be used to identify patients at risk for IAFE.
Clear drapes are used to observe any abdominal distension throughout the procedure.
Collect fluid using puddle vacuums and suction mats to properly calculate the fluid deficit.
Informing the surgeon of the fluid deficit every 15 minutes is important for detecting major fluctuations.
Communication between the anesthesiologist and surgeon is critical for detecting early signs of symptomatic IAFE.
<b>Pitfalls</b>
No direct clinical correlation between amount of fluid deficit and ACS.
Not accounting for fluid that falls on the floor can result in underestimated fluid deficit calculations.
Lack of communication between staff and surgeon may result in unnoticed symptomatic IAFE and ACS.

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IAFE, intrabdominal fluid extravasation; ACS, abdominal compartment syndrome.



**Table 3.** Advantages and Disadvantages**Advantages**

- Quick and simple to perform with standard available equipment.
- Does not need technical expertise or training.
- Can account for fluid extravasated into anatomical spaces that other methods may fail to measure.
- Can be used in conjunction with other methods of monitoring fluid extravasation.
- Allows the surgeon to monitor fluid deficit in real time.

**Disadvantages**

- Unable to directly observe fluid extravasating into abdominal cavity.
- Precise fluid deficit cannot be calculated due to fluid estimations in the intravenous bags and the Neptune system.
- Proposed fluid deficit of 1500 mL is based on anecdotal evidence.

IAH elevations can be seen in patients with ascites, large abdominal tumors, pregnancy, or obesity. These patients may be at a higher baseline risk for development of ACS at lower levels than expected.

Despite these limitations, this technique offers an objective approach to calculate intra-abdominal fluid extravasation, while allowing the surgeon to closely monitor for ACS (Table 3). ACS is a devastating complication that must be avoided at all costs, and this simple method gives the surgeon intraoperative control over preventing it.

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