Venous Air Embolism During Operative Hysteroscopy

Philip G. Brooks

Introduction

A rare, but devastating complication of operative hysteroscopy is venous air entrapment and subsequent room-air embolization. While this phenomenon has been reported to occur during neurosurgical (1) and urological (2) surgery and at caesarean section (3), its occurrence during operative hysteroscopy has been cited only in obscure instances except as a complication of the inappropriate use of a dextran pump (4). Two cases were reported in letters to the editor of an anesthesia journal (5, 6), and one case was described in a letter to a British medical journal (7). Corson, in a recent publication on endoscopic air embolism in general (8), included several cases of hysteroscopic air embolism complications, some of which are included in this chapter. The author has been asked to review seven additional cases of this complication, either as a consultant for a hospital peer-review process or as an expert in a litigation. This chapter will describe these cases and the pathogenesis of this problem, with recommendations for its prevention and management when it occurs. Because some cases are still pending, they will be presented anonymously and with intentional minor changes.

Pathogenesis

In neurosurgery, when procedures are performed with the patient in the sitting position in order to gain access to posterior lesions, it is well recognized that, unless the brain is bathed in saline solution, opening venous sinuses in the calvarium or dura will permit venous air aspiration. This situation arises due to the fact that, because the heart is below the level of the brain, a negative intravenous pressure occurs with each diastolic relaxation of the heart (1). Such an event occurs in 25% to 50% of such neurosurgical operations, depending on the detection method. Once the air enters the venous circulation, foaming appears in the right side of the heart and blood outflow becomes obstructed, increasing the pulmonary arterial pressure. Early in the development of problem, end-tidal CO₂ declines; ultimately, circulatory collapse and cardiac arrest occur. Because the pressure increases in the right side of the heart to levels higher than those in the left heart, the previously closed foramen ovale may open in more than 15% of adult patients resulting in paradoxical embolism to the brain and other organs (1).

In gynecological procedures, the identical mechanism exists. Instead of the patient in the sitting position however, his or her head is tipped down, putting the heart below the level of the uterus. If the surgeon opens some of the large sinuses deep in the myometrial wall and leaves an open passage to the outside, room air is aspirated into the venous circulation.

Review of cases

In addition to the three cases cited earlier from letters to the editors, seven cases of venous air embolism personally reviewed by the author are summarized in Table 44.1. Five of the patients were undergoing hysteroscopy for the management of abnormal uterine bleeding, one of which was following a spontaneous abortion. The other two were undergoing repair of intrauterine defects for fertility reasons, one a congenital defect (septum) and one an acquired defect (uterine synechiae). Five of these patients were stated to be in a Trendelenburg position; one was reported not to be tipped; and the other had no statement as to the degree of tip. Difficulty with dilatation of the cervix was reported in three of the seven procedures, two indicated no such difficulty, and no information was available on the other two. No correlation was found between the development of air embolism and the distention medium used, with three procedures employing carbon dioxide at appropriate flow and pressure, and three using different low-viscosity liquids; the remaining case had not yet started the hysteroscopy, as the first sign.
Table 44.1. Summary of cases of venous air embolism occurring at operative hysteroscopy.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Uterine septum</td>
<td>Yes</td>
<td>n/s</td>
<td>CO₂</td>
<td>35 s</td>
<td>↓ E-T CO₂ ↓ PO₂</td>
<td>D.I.C., death</td>
</tr>
<tr>
<td>2</td>
<td>Abnormal bleeding</td>
<td>n/s</td>
<td>Yes</td>
<td>CO₂</td>
<td>9 min</td>
<td>Bradycardia; Doppler = bubbles, both sides of heart; septal defect</td>
<td>Coma, death</td>
</tr>
<tr>
<td>3</td>
<td>Abnormal bleeding</td>
<td>Yes</td>
<td>No</td>
<td>CO₂</td>
<td>10 min</td>
<td>Mill-wheel murmur; ↓ E-T CO₂ ↓ PO₂; Doppler = bubbles, both sides of heart</td>
<td>Hyperbaric chamber, survived</td>
</tr>
<tr>
<td>4</td>
<td>Menorrhage</td>
<td>Yes</td>
<td>Yes</td>
<td>None</td>
<td>“after D&amp;C only”</td>
<td>Bradycardia; ↓ E-T CO₂; CVP line withdrew bubbles</td>
<td>Death</td>
</tr>
<tr>
<td>5</td>
<td>Menorrhage</td>
<td>No</td>
<td>Yes</td>
<td>Glycine</td>
<td>15 min</td>
<td>↓ E-T CO₂ ↓ PO₂; mill-wheel murmur.</td>
<td>Resuscitated, recovered</td>
</tr>
<tr>
<td>6</td>
<td>Incomplete abortion</td>
<td>Yes</td>
<td>No</td>
<td>Ringer’s lactate</td>
<td>15 min</td>
<td>↓ PO₂ ↓ E-T CO₂; CVP line withdrew &gt;50 cc. bubbles</td>
<td>Death</td>
</tr>
<tr>
<td>7</td>
<td>Synechiae</td>
<td>Yes</td>
<td>n/s</td>
<td>Saline</td>
<td>&lt;10 min</td>
<td>↓ PO₂; Bradycardia; inguinal crepitation; gas recovered from femoral vein and cardiac taps</td>
<td>Death</td>
</tr>
</tbody>
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n/s = not stated.
E-T = end-tidal.

of trouble occurred at the end of a preceding dilation and curettage.

All of the complications emerged within 15 minutes after beginning the actual operative procedure. In each case the earliest signs of problems were dramatic changes noted by the anesthesiologist. These signs included either a sudden fall in end-tidal CO₂ measurements, bradycardia, a fall in oxygen saturation, or the presence of the classic sign of air in the heart, a mill-wheel type of murmur auscultated over the precordium. Confirmation of the presence of gas in the circulation was achieved in two cases with the use of emergency echocardiography and by needle or central venous pressure catheter aspiration in three others.

Five of the seven patients died from the complication, with the other two recovering. One recovery was attributed to the brilliance of the anesthesiologist in turning the patient onto her right side, rapidly infusing physiologic saline solution intravenously, confirming the condition with a transesophageal echocardiogram, and ordering the transfer of the patient to a hyperbaric chamber.

Discussion

Drawing from the understanding of the development of venous air embolism during other surgical procedures, a fairly clear pattern emerges as to how this complication happens during operative hysteroscopy. Very often—if not for every procedure—the patient's position on an operating table places the level of the heart and vena cava below the level of the uterus; this differential is often accentuated by requesting that the head of patient be tipped even more downward (Fig. 44.1), mainly so that weighted specula stay in place better. With the current use of video cameras for hysteroscopic procedures, almost no other reason exists to tip the patient.
When operative instruments are to be used, their larger caliber requires that the cervix be dilated more than with diagnostic instruments. This process can result in either occult lacerations and false passages at the level of the internal cervical os, or in partial penetrations into the myometrial wall at the top of the fundus from a partly blunt dilator “popping” through the cervix after considerable force is applied to dilate the canal. At that point, while the surgeon is assembling and readying the operative instruments, the cervix and vagina are left open to room air and the negative pressure in the vascular tree literally sucks the air in.

Evidence for large sinus communication with the venous circulation has been shown brilliantly by Garry (9). In this research, following a biopsy deep into the myometrial wall, dye instilled at intrauterine pressure higher than venous pressure was seen radiographically to flow into the venous system at flow rates sufficient to give a clear venogram (Fig. 44.2). That cardiorespiratory function is altered so soon after the beginning of the procedure attests to the fact that the bubbles noted must be room air, as carbon dioxide (used in three of the cases) has a wide margin of safety at the flow rates and pressures used in hysteroscopy, even if insufflated directly into the venous circulation (10). Because of its high solubility in plasma, it would take much more time or much higher flow rates to create this condition using carbon dioxide.

Detection and management

Figure 44.3 shows the sensitivity of methods used to detect the presence of gas in the heart and great vessels and to monitor the subsequent physiological changes (8). Echocardiography, either by transesophageal probe or by precordial Doppler, may be the most sensitive technique to detect as little as 0.5 mL of gas bubbles in the heart (1). Neither method is widely used by anesthesiologists, especially for “low-risk” gynecological procedures, because of the high false-positive readings obtained. As noted in the case summaries, however, both techniques were used to define and document the event.
As more air enters the bloodstream, the fall in end-tidal CO₂ is highly sensitive and specific for embolism. Most patients undergoing general anesthesia today are monitored by capnography, making this one of the most important early signs. If a central venous pressure catheter is placed, either prior to the procedure (for high-risk patients) or during the procedure (as difficulties arise), elevation of intracardiac and pulmonary arterial pressures can be detected and monitored. Aspiration of the bubbles, when detected, can assist in the correction of the problem. As more gas is entrapped, the increasing resistance to blood flow results in hypoxia, decreased cardiac output, hypotension, tachypnea, and cardiac arrest. Resuscitative efforts at this point might be aided by stopping the source of the air inflow, turning the patient onto her right side, attempting to aspirate the bubbles as much as possible and flushing the circulation with a large saline bolus.

Prevention

The events in venous air embolism are so sudden and so severe as to make their management extremely difficult. Consequently, this complication often results in death or severe disability. It is obvious that prevention is the most important lesson from the review of this problem.

To begin with, avoid putting the patient in the Trendelenburg position. As noted earlier, the use of video cameras essentially eliminates the need to tip the patient head-down. Dilate the cervical canal with care, attempting to avoid lacerations and partial penetrations into the myometrial wall. After the dilation, do not leave the cervix and vagina open to room air for any length of time. If the instruments were not prepared before the dilation is performed, allow the vagina to close or place a wet gauze sponge or packing against the cervix while they are assembled. Another suggestion would be to leave the last dilator in the cervical canal until the surgeon is ready to insert the hysteroscope and start the distention gas or liquid flowing. The best protection against a complication due to venous air embolism is understanding how it develops.

REFERENCES

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Objective: To alert gynecologic surgeons to the risk of room air embolism during endoscopy.

Design: Case reports.

Setting: Medico-legal consultations.

Patients: Five women having endoscopic procedures.

Interventions: Endoscopy followed by emergency resuscitative measures.

Results: Morbidity and mortality.

Conclusions: The risk of room air embolism may be lessened by attention to the operative technique and by monitoring the end tidal carbon dioxide levels.

Key Words: Gynecologic endoscopy, hysteroscopy, laparoscopy, room air embolism

Risks of air embolism during obstetric and/or gynecologic operative procedures were documented before the advent of endoscopic technology. Even nonsurgical procedures, such as entry of air into the placental sinusoids during orogenital sexual activity during pregnancy, can result in death (1). The famous gynecologic surgeon, C. Lee Buxton (2), described patient mortality in a case where room air was used to test tubal patency during surgery. Death has been described from misconnected suction machines when the exhaust tubing was placed into the uterine cavity (3). There also is an extensive literature on cesarean section-related room air emboli (4–7) as well as room air embolus occurring during hysterec- tomy (8).

Gynecologic endoscopic procedures introduce the insufflating gas as another possible source of embolic phenomenon. The increased solubility of carbon dioxide, which is the commonly used gas for peritoneal distension and the only gas used for hysteroscopy, is expected to give a wide margin of safety compared with room air.

Functioning as medico-legal consultants and reviewers, the authors have collected a series of gas embolic accidents occurring during gynecologic endoscopy. These cases are presented to alert the gynecologist to these risks and to mention methods of early diagnosis and some maneuvers designed toward possible prevention of these catastrophic occurrences. Because specific therapy usually is within the province of the anesthesia team, aspects of acute management will not be discussed.

CASE REPORTS

Case 1

A 27-year-old woman had sustained postpartum hemorrhage and a curettage was performed on two separate occasions. Subsequently, she developed amenorrhea. A hysterosalpingogram was diagnostic for severe uterine cavity adhesions. Of note was significant intravasation of the dye during the study.
A few weeks afterward, she was taken to the operating room, given general inhalational anesthesia, and her cervix was dilated to 7 mm in order to accommodate a hysteroscope. Uterine distention was created with saline delivered by gravity flow with the gradient of the pressure being approximately 1 m between the bag and the patient. She was in a "moderate" Trendelenburg position. The hysteroscope was removed to change over to an operating sheath; before reinsertion, the anesthesia team noted a sudden and marked decrease in heart rate, falling oxygen saturation levels, falling blood pressure, and cyanosis. Crepitance was detected in both inguinal areas and a femoral venous tap produced frothy blood. Gas was aspirated from both cardiac ventricles. Despite resuscitative efforts the patient died.

Case 2

A 27-year-old nulligravida was taken to the operating room for hysteroscopic examination because of abnormal uterine bleeding resistant to hormonal therapy. Under general anesthesia, cervical dilatation to 5 mm was achieved with some difficulty, after which the hysteroscope was inserted with carbon dioxide at 70 mm Hg pressure (flow rate unknown) delivered with a standard hysteroscopic gas source. Before any surgical manipulation other than inspection of the cavity, bradycardia developed at 9 minutes into the case (total anesthesia time) and atropine was given IV. Cardiac asystole ensued. Transesophageal ultrasonography demonstrated gas in all four chambers of the heart and a large atrial septal defect was noted. The vagina was packed to prevent further entry of room air (the presumed cause). She was comatose for 7 days after resuscitative efforts. The family and her medical attendants agreed on removal of life support systems but were overruled by the Medical Ethics Committee. Subsequently, she made a good recovery but sustained permanent brain damage.

Case 3

A 32-year-old patient was brought to the operating room for diagnosis and possible therapy after three consecutive pregnancy losses in the late first and early second trimesters. Laparoscopy, performed without apparent incident, disclosed a broad uterine fundus. After cervical dilatation, a hysteroscope with an operating sheath for optical scissors was introduced into the uterine cavity with the patient in the "usual Trendelenburg attitude." Carbon dioxide delivered at a maximum of 15 mL/min and at a maximum of 90 mm Hg pressure was used as distention. The septal incision was begun and the real-time video recording documents that at 35 seconds from the initial incision there was considerable bleeding. The hysteroscope was removed in order to clear the lens as the vision became obscured. Within 2 minutes, anesthesia alarm systems were activated; end tidal CO2 plummeted, oxygen saturation decreased, and bradycardia was noted. Cardiac puncture produced gas but it was not analyzed. She was resuscitated and then developed disseminated intravascular clotting. The patient was transferred from the community hospital to a university center but then developed renal shutdown. Brain waves ceased and at 10 days life support systems were removed. Autopsy showed no thrombus formation in the heart and no atrial septal defects. No uterine perforation or laceration was seen.

Case 4

A 32-year-old patient complaining of chronic pelvic pain and abnormal uterine bleeding unresponsive to hormonal therapy was taken to the operating room for dilatation and curettage (D&C) and laparoscopy. She was 152.5 cm tall but weighed 109 kg. Under general anesthesia with intubation, a dilatation and curettage was performed without incident. An open-ended intrauterine cannula-manipulator was inserted into the uterus and the peritoneal cavity was distended with N2O with a Veress needle placed via the umbilicus. The laparoscopy then was done in the usual fashion as a diagnostic procedure. Because of her obesity, the patient was placed in a steeper Trendelenburg position than usual. Vigorous manipulation with the uterine manipulator was necessary to help the surgeon visualize pelvic structures. At the end of the procedure, the gas was released from the abdominal cavity and the patient then was placed in the supine position. A suture was used to close the umbilical wound. As the patient was about to be extubated, the cardiac monitor alarm was activated, blood pressure fell, and a convulsion occurred. A millwheel murmur over the heart was detected and the patient was placed immediately on her left side. Needle aspiration of the heart showed frothy blood. Despite resuscitative efforts, the patient died within minutes. The eye grounds showed small bubbles in the retinal arteries.

At autopsy the heart was filled with gas in all four chambers and an atrial septal defect was seen. The meningeal arteries also had gas within the lumen. Before the heart was opened, a sampling of the gas was made and sent for analysis; the gas proved to be room air.

During the postmortem discussions, attention was paid to the fact that because of the patient's habitus, which necessitated a steep head-down position, the
handle of the uterine cannula was at least 26 cm above the level of the heart. It was proposed that with the active manipulation a passage was created such that room air was sucked into the uterine cavity and through a venous sinus opened by the D&C procedure and then into the major vessels leading back to the heart. Because of the low venous pressure and the Trendelenburg position, the bolus of air may not have traveled to the heart until the patient was returned to the supine position.

**Case 5**

The patient was a 48-year-old with a history of abnormal uterine bleeding, dysmenorrhea, and associated anemia nonresponsive to hormonal treatment. An endometrial ablation was planned. Under general inhalation anesthesia, cervical dilatation to 9 mm was performed and suction curettage was accomplished. As the resectoscope was inserted into the uterus but, before the stopcocks were opened to admit the distending liquid medium, end tidal CO₂ was noted to fall precipitously and cardiac arrest ensued. Resuscitation efforts were initiated and a central IV line was inserted. Approximately 15 mL of air was aspirated immediately, presumably from the right atrium via the superior vena cava. The patient died.

**DISCUSSION**

The prevalence of these tragic accidents is unknown. Incidents involving low degree of transient morbidity without permanent damage probably are unreported. We have collected 10 cases in all, and at least four represent embolism after D&C before or unassociated with hysteroscopy. Diagnostic hysteroscopy usually performed with small bore instruments requiring little or no cervical dilatation probably constitutes an immeasurably small risk. Dilatation to 10 mm to accommodate resectoscopes and operating sheaths is more likely to cause cervico lower segment lacerations.

The literature on cesarean section-related room air embolus is understandable given the presence of large retroplacental sinusoids as conduits for entry of air into the circulatory system, especially when a deep Trendelenburg position is maintained and the placenta is elevated above the level of the heart, remembering that pressure within the inferior vena cava during systole is actually negative to room air pressure. The same phenomenon or mechanism of entry is probably operative during endoscopic procedures in which uterine venous channels become opened during hysteroscopic procedures, as a consequence of traumatic dilatation of the cervix, from a preceding D&C, or with entry of room air via a uterine open-ended manipulator during laparoscopy.

That insufflation of the peritoneal cavity with CO₂ is a safe procedure when performed with properly designed and functioning equipment was suggested by an early study by Lindemann et al. (9) in large German Shepherd dogs. But work by Root et al. (10) in dogs after an operative death during laparoscopy, suggested that CO₂ could be trapped within the portal system with a delayed embolus. In their patient, a patent foramen ovale was detected at autopsy. When the right side of the heart has its outflow tract occluded with gas bubbles, gas can appear in the left chambers of the heart as the right side pressure increases if there is a patent foramen ovale or a septal defect. However, in the case of Root et al. (10), as with two other cases reported in the literature (11, 12), a D&C was performed first, raising the possibility that the actual culprit was room air entering the venous circulation via the vagina and the uterus as opposed to a carbon dioxide pneumoperitoneum-related mechanism.

Because of its great solubility in blood CO₂ affords a great margin of safety in procedures where it is used to distend the relatively avascular peritoneal cavity and the uterus as well. Corson et al. (13) studied the cardiopulmonary effects of direct insufflation of CO₂ into the femoral vein of the adult ewe. Up to 90 mL/minute was delivered directly into the femoral vein. Provided that the animals were hyperventilated to prevent acidosis from this increased metabolic load, cardiopulmonary parameters remained within reasonable values. Pulmonary artery pressure did increase with time, and cardiac output increased as well. Oxygen saturation was within normal limits and in only one animal was any cardiac abnormality at all seen on the tracing, and this was in the form of premature ventricular contractions. Because these animals weighed between 24 and 32 kg, the conclusion was drawn that for the adult woman there was a large margin of safety for leakage of CO₂ into the vascular system with respect to disruption of metabolic parameters and cardiopulmonary function. So far as embolus was concerned, because CO₂ is so soluble in blood (54 mL/dL), true CO₂ embolus from therapeutic procedures should be very rare. But as shown by Baggish and Daniell (14), this safety margin can be overcome when high flow rates of CO₂ are delivered to the uterus as with a neodymium:yttrium-aluminum-garnet laser fiber where the cooling of the fiber with CO₂ is in the neighborhood of a 1 to 3 L/minute flow rate.

Our cases 3 and 5 probably have similar mechanism of action in which the integrity of the endometrium was disturbed and air in the uterine cavity was forced into the circulatory system as a conse-
Venous Air Embolism Monitoring

Figure 1 Methods of threshold detection of cardiovascular gas embolism versus increased rate of entry into the circulatory system.

Table 1 Methods of Minimizing Room Air Embolism

- Careful monitoring of end tidal CO2
- Nontraumatic cervical dilatation
- Preoperative osmotic dilators in selected cases (nonparous patients, prior cervical surgery)
- Avoidance of steep Trendelenburg position
- Prophylactic dilute pitressin injection in cervix
- Lessen exposure of dilated cervix to room air
- Remove weighted vaginal speculum
- Place the last dilator used in cervix
- Consider occluding the vagina with a sponge
- Fill hysteroscopic system with fluid before insertion into uterus

Avoidance of deep Trendelenburg position seems desirable. A steep head down tilt may be necessary for certain laparoscopic procedures, but it is not a necessity for hysteroscopy. Traumatic cervical dilatation cannot be avoided always, especially after prior cervical cone biopsy and other procedures. In such cases, use of osmotic dilatation preoperatively may be helpful. When it occurs, however, extension of the laceration into the lower segment of the uterus with tearing of the cervical vessels must be considered. Previous roentgenogram documentation of intravasation during infusion of dye also should alert the clinician to a situation in which the patient is operatively at greater risk. Excessive bleeding during hysteroscopy is an obvious sign that exchange of gas and blood by necessity must occur as the vessels are opened. We have been impressed with the size of blood vessels seen in submucous myomas and also with the vascular supply in cases of multiple uterine polyps. Prophylactic use of pitressin to induce contraction of the uterus and the vascular tree in that organ may offer some protection. A recent study showed decreased operative bleeding and reduced intravasation of liquid media during hysteroscopic surgery when pitressin was used prophylactically (16).

If a D&C is to be performed, a decreasingly used procedure given the direct visual accuracy afforded by hysteroscopy, consideration should be given to making it the last, rather than the first, procedure performed. When uterine manipulators are used with a channel for delivery of fluids for tubal perfusion, the simple expedient of capping the exposed opening should be followed. All these suggestions and admonitions (Table 1) follow logical, albeit unproven, reasoning and there is no documentation that these preventive measures actually will decrease an admittedly rare complication. Yet, the prevention of mortality in what generally is considered to be a minor operation through exercising increased uterine instruments, and occlusion of the open cervix and vagina as countermeasures. Whether a change in patient position is truly helpful is debatable.
vigilance and by instituting easily performed safety measures is prudent. It is hoped that this report, if it has no other effect, will serve to alert the gynecologic surgeon to the risk and possible prevention of room air embolus during endoscopy.

REFERENCES

because of the potential for this complication they regard the use of saline, rather than air, should be mandatory when locating the epidural space in patients who are to undergo ESWL.

A recent report has further implicated the use of air to locate the epidural space with the development of neurological complications. A 52-year-old woman was described in whom a lumbar epidural was inserted to treat chronic back pain. She subsequently developed incomplete analgesia during epidural anaesthesia. Anesthesiology 1991; 74:190-1.

We suggest that in the case reported by Deam and Scott, neurological damage may have resulted from subcutaneous emphysema and venous air emboli. Several episodes of air embolism have also been recorded, two of these occurring in patients breathing spontaneously and it was suggested that an auxiliary evacuation device was used. Endometrial ablation was performed with a loop resectoscope, 1.5% glycine and an Ellick evacuator used as in transurethral resection of prostate surgery. About 15 minutes into the procedure the SpO₂ suddenly fell to 92% and EtCO₂ to 18 mm Hg. The BP at this stage was 90/60 and pulse was 60 bpm. Auscultation of the heart and chest revealed a mill-wheel murmur and normal breath sounds. Despite immediate manual ventilation with 100% the O₂, saturation and ETCO₂ continued to decrease. The procedure was abandoned and the patient placed in the left lateral position. A 14 gauge cannula was inserted peripherally and 1 litre of Hartmann's solution infused. A triple-lumen catheter was inserted into the right internal jugular vein but no air was aspirated. At this stage the SpO₂ was 68% EtCO₂ 32 mm Hg. The pulse was 30 bpm and the BP was unrecordable. Asystole followed and external cardiac massage was immediately commenced while atropine 1200 mcg and adrenaline 1 mg were given intravenously. After about 30 seconds the pulse had returned to 140 bpm and BP was restored to 140/80. The peak inspiratory airway pressure was 40 cm H₂O and auscultation of chest revealed mild bronchospasm. Two heart sounds were audible with no other added sounds.

The patient was transferred to the Intensive Care Unit for monitoring and extubated one hour post cardiac arrest with no subsequent sequelae.

Cardiac Arrest During Endometrial Ablation

A 36-year-old previously well woman presented to the Day Surgery Unit for endometrial ablation. She had had one uncomplicated general anaesthetic 10 years ago. No premedication was given. Anaesthesia was induced with propofol 150 mg, fentanyl 100 mcg and droperidol 1 mg, and intubation of the trachea was facilitated with vecuronium 6 mg. The lungs were ventilated with nitrous oxide, oxygen (FiO₂ 0.3) and isoflurane 0.7% min. with a total fresh gas flow of 2 l/min. Monitoring consisted of ECG, noninvasive blood pressure (BP), pulse oximetry and capnography (EtCO₂). Her BP was stable at 120/80, heart rate 50-60 bpm, O₂ saturation 98% and EtCO₂, 32 mm Hg. The patient was placed in the lithotomy position with slight head-up tilt. Endometrial ablation was performed with a loop resectoscope, 1.5% glycine and an Ellick evacuator used as in transurethral resection of prostate surgery.

About 15 minutes into the procedure the SpO₂ suddenly fell to 92% and EtCO₂ to 18 mm Hg. The BP at this stage was 90/60 and pulse was 60 bpm. Auscultation of the heart and chest revealed a mill-wheel murmur and normal breath sounds. Despite immediate manual ventilation with 100% the O₂, saturation and ETCO₂ continued to decrease. The procedure was abandoned and the patient placed in the left lateral position. A 14 gauge cannula was inserted peripherally and 1 litre of Hartmann's solution infused. A triple-lumen catheter was inserted into the right internal jugular vein but no air was aspirated. At this stage the SpO₂ was 68% EtCO₂ was 32 mm Hg pulse was 30 bpm and the BP was unrecordable. Asystole followed and external cardiac massage was immediately commenced while atropine 1200 mcg and adrenaline 1 mg were given intravenously. After about 30 seconds the pulse had returned to 140 bpm and BP was restored to 140/80. The peak inspiratory airway pressure was 40 cm H₂O and auscultation of chest revealed mild bronchospasm. Two heart sounds were audible with no other added sounds.

The patient was transferred to the Intensive Care Unit for monitoring and extubated one hour post cardiac arrest with no subsequent sequelae.

As in Dr Michael's case, air embolism has been reported previously in association with loop diathermy endometrial ablation, possibly from air in the glycine bag or tubing. One episode occurred in a patient breathing spontaneously and it was suggested that an anaesthetic technique employing positive pressure ventilation may be preferred. Several episodes of fatal air embolism have also been recorded, two of these during endometrial ablation using neodymium: YAG laser.
Anaesthetists should be aware that this procedure absorption of glycine, all of which can present in the first 3 litre bag of glycine still contained 2 litres.

In this case I believe air was introduced via the Ellik evacuator as the incident occurred after 15 minutes and the first 3 litre bag of glycine still contained 2 litres (deficit 200 ml). Other possibilities include an acute vasovagal episode, allergic reaction or excessive absorption of glycine, all of which can present in a similar fashion. The presence of a mill-wheel murmur makes air embolism the most likely diagnosis. Anaesthetists should be aware that this procedure carries a risk of significant air embolism.

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References

Selectatec gas leak

I wish to report an incident which involved a leak at the connection between a Cyprane Selectatec manifold, mounted on a newly acquired Ulen Minor anaesthetic machine and a Penlon PPV Sigma isoflurane vapouriser.

Two children were scheduled to be anaesthetised for CT scan. The anaesthetic machine was checked with a Fluotec 3 halothane vapouriser in place. The same anaesthetic technique was used for both patients. The first procedure, which lasted about 15 minutes, was uneventful. The second patient weighed 15 kg and, in addition to the CT scan, was to have auditory evoked potentials recorded as part of assessment for suitability for insertion of cochlear implant. An inhalational induction using halothane and nitrous oxide in oxygen was performed and a laryngeal mask airway inserted. Monitoring included capnography and nitrous oxide and oxygen analysis using side-stream gas sampling (Datrex Oscar Oxy™). The halothane Fluotec 3 was then removed and replaced with the isoflurane vapouriser, which locked easily onto the Selectatec. This Penlon vapouriser had been used without problem on other machines in the department but, unknown to the anaesthetist, not with this particular machine.

The CT scan took about 15 minutes, the child and anaesthetic machine were then moved into an adjacent room for the evoked-potential recording. The monitors were reconnected and after time had been allowed for re-equilibration it was noticed that the displayed value for the inspired concentration of oxygen (FiO2) was 21%. The rotameters, as set, should have given FiO2 33%. The side-stream port was disconnected and the accuracy of the oxygen analyser confirmed using room air. The presence of a large leak was suggested by the failure of the reservoir bag of the '1-piece breathing system to inflate when the distal end was occluded. It was assumed that air was being entrained. As the source of the leak was not immediately apparent the nitrous oxide was discontinued and oxygen and isoflurane administered, with an increased fresh gas flow, to ensure an adequate FiO2. The maximum FiO2 achieved was 57% (FiN2O=0), with a fresh gas flow of 8 l min⁻¹. The isoflurane concentration set on the vapouriser was 2%. Pe' of CO2 remained at 48 mm Hg, with a respiratory rate of approximately 28 min⁻¹ but the child’s respiratory pattern became more irregular, with occasional sighs, consistent with a decreasing depth of anaesthesia. After approximately 15 minutes, as the recording was nearing completion, the child woke suddenly and removed the laryngeal mask.

The machine was examined after the procedure. With less background noise a leak was clearly audible at the proximal connection between the Selectatec manifold and the Penlon vapouriser. There was no leak without a vapouriser on the machine nor with the Fluotec 3 on the Selectatec. The machine and vapouriser were removed from service and the supplied contacted. He examined the machine and found that the rear portion of the Selectatec vapouriser, which contained the Interlock mechanism, overlapped the back bar. The difference in height between the machine back bar and the Selectatec was lifting the vapouriser off the manifold, preventing an adequate seal between the O ring of the Selectatec manifold and the vapouriser. The Fluotec 3 vapourisers do not have the Interlock system to inflate when the distal end was occluded. It was assumed that air was being entrained. As the source of the leak was not immediately apparent the nitrous oxide was discontinued and oxygen and isoflurane administered, with an increased fresh gas flow, to ensure an adequate FiO2. The maximum FiO2 achieved was 57% (FiN2O=0), with a fresh gas flow of 8 l min⁻¹. The isoflurane concentration set on the vapouriser was 2%. Pe' of CO2 remained at 48 mm Hg, with a respiratory rate of approximately 28 min⁻¹ but the child’s respiratory pattern became more irregular, with occasional sighs, consistent with a decreasing depth of anaesthesia. After approximately 15 minutes, as the recording was nearing completion, the child woke suddenly and removed the laryngeal mask.

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Venous Embolism of Diathermy Evolved Gases Complicating Endometrial Ablation using Glycine Irrigant

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SUMMARY
A case is reported of venous gas embolism in a 44-year-old woman undergoing hysteroscopic endometrial ablation using glycine irrigation without gas insufflation. The postulated source of gases are the vapour and combustion products produced by the diathermy.

Key Words: EMBOLISM: venous, air, hysteroscopy, diathermy

Venous gas embolism under anaesthesia is normally associated with the entry of insufflating gas or air into the bloodstream. In the following report however no gas insufflation was used.

CASE HISTORY
A 44-year-old female of ASA grade 1 presented for hysteroscopic endometrial ablation. Planned spinal anaesthesia was performed. The height of the spinal blockade, however, was inadequate for the procedure and anaesthesia was supplemented with a bolus of propofol followed by placement of a laryngeal mask. Anaesthesia was maintained by isoflurane 1 to 2% in 35% oxygen and 65% nitrous oxide with spontaneous ventilation.

Endometrial ablation was commenced after positioning the patient in the lithotomy position. Initial examination and hysteroscopy showed a markedly anteverted uterus. Warmed glycine 1.5% was used as an irrigant at a pressure of 75 to 80 mmHg via a controlled pressure irrigation pump (Zimmer, Blackburn, Vic.). Surgery proceeded for 30 minutes although the surgical field was impaired more than usual by bubbles derived from the diathermy of tissues. The diathermy electrode used consists of a metal ball rolling on a fixed axis between two supporting wires (Olympus Australia Ltd). The ball was otherwise free in the uterine cavity. There was no gas cooling or insufflation system.

Forty minutes after the commencement of general anaesthesia, the pulse oximeter indicated a sudden decrease in oxygen saturation (SpO₂) from 97% to 92%. The patient’s pulse was easily palpable with systolic blood pressure unchanged and normal ventilatory pattern. The end-tidal carbon dioxide (P<sub>ET</sub>CO₂) was noted to be 24 mmHg during spontaneous ventilation. On auscultation of the heart a tinkling sound similar to that of an ornamental fountain was heard widely over the precordium. A diagnosis of venous gas embolism was made, the patient commenced on 100% inspired oxygen and surgery was ceased. The SpO₂ rose promptly to 98% and other observations remained stable. Review of the automatically recorded observations showed a gradual fall in the P<sub>ET</sub>CO₂ over approximately ten minutes before the drop in saturation, this had been accompanied by an increase in pulse rate from 62 to 75 beats per minute and an increase in diastolic blood pressure from 45 to 60 mmHg. The heart sounds remained abnormal for two to three minutes gradually becoming less distinct. As haemostasis was good and surgery completed, no further diathermy was used, and measured glycine loss was 300 ml. Anaesthesia was continued with isoflurane in oxygen for 30 minutes and then the legs lowered from lithotomy and isoflurane discontinued. The patient regained consciousness uneventfully.

DISCUSSION
Venous gas embolism has been reported in many cases in association with direct insufflation of gas into the uterus. A Medline search failed to find any report of clinical venous gas embolism in association with diathermy evolved gases.

The diagnosis in this case was suggested by the unusually low P<sub>ET</sub>CO₂ and confirmed by the distinctively abnormal cardiac sounds. CO₂ measured at the upper airway or distal anaesthetic circuit is influenced by the respiratory pattern. During anaesthesia with
spontaneous ventilation the length of expiration may be insufficient to allow the end-tidal measurement to reflect a true mixed alveolar gas. This case demonstrates the effectiveness of airway CO2 monitoring in spontaneously ventilating patients.

In the absence of altered inspiratory gas a reduction in the $P_{\text{ET}}\text{CO}_2$ is caused by a change in the balance between minute ventilation and the quantity and distribution of CO2 presented to the lung in the blood via the pulmonary artery. This balance may be altered by sudden reductions in cardiac output, major changes in regional perfusion of the lung, reduced body production of CO2 or increased ventilation.

Gas emboli occupy superior parts of the pulmonary arterial tree causing a reduction in perfusion to the upper zones and therefore increased deadspace ventilation. In the absence of a severe reduction in cardiac output this is probably the main mechanism of reduction of $P_{\text{ET}}\text{CO}_2$ in gas embolism.

Cardiac output may be reduced due to the displacement of blood from the heart and altered cardiac valve function in the presence of gas. Ineffective cardiac pumping is seen in dogs with a bolus of 3 to 8 ml/kg air. In the case reported here, a modest reduction in cardiac output was manifest as an increase in diastolic blood pressure and pulse rate, reflecting reflex changes to maintain blood pressure in the face of decreased cardiac output. In the event of cardiac output decreasing suddenly, there is an immediate fall in the total quantity of CO2 presented to the lung through the pulmonary circulation. This returns to normal once venous CO2 concentration increases to maintain body CO2 equilibrium. In the absence of a catastrophic fall in cardiac output the magnitude of this effect is relatively small as only approximately 10% of the available CO2 in the blood is normally transferred to the alveolus. Any fall in the partial pressure of alveolar CO2 will cause extra readily available CO2 to pass into the alveolus limiting any further fall in $P_{\text{ACO}_2}$. A substantial decrease in cardiac output will also produce an increase in deadspace ventilation with upper zones in the lung receiving negligible perfusion compared with lower zones.

Adornato et al. noted two distinct abnormalities in cardiac auscultation during air embolism in dogs. At mean infusion rates of 1.7 ml/kg/min or a bolus of 25 ml (1.2 to 2.5 ml/kg) a tinkling drum-like sound was heard. At mean infusion rates of 1.96 ml/kg/min or a bolus of 200 ml (9.5 to 20 ml/kg) the classic millwheel murmur was heard. The 200 ml bolus was uniformly fatal. The abnormal heart sounds heard in this case had a distinct tinkling quality and probably correspond to the drum-like sound heard in dogs. Although it is useful to confirm the diagnosis, the late and unpredictable onset of this sound restricts its usefulness.

In this case the only possible source of gas was bubbles evolved from the endometrial diathermy. These obscured the surgical field at times due to inadequate clearance through the endoscopic sheath. The pronounced anteverision of the uterus caused these bubbles to accumulate in the superior part of the uterine cavity under pressure from the infuser containing the glycine irrigant. This created a strong gradient favouring the entry of gas into the circulation. Gas evolved from a diathermy contains water vapour and products of combustion. The water vapour will rapidly condense leaving CO2 as the major embolizing gas. Some particulate matter (smoke) may also be present from the combustion. Fine particulate matter is filtered in the pulmonary circulation and removed by phagocytosis.

Most gas emboli reaching the pulmonary circulation will pass through the pulmonary-alveolar membrane and be eliminated. Intravascular bubbles are not inert and cause platelet and leucocyte aggregation, disrupt endothelium and activate the complement and kinin systems. This coating of blood components and damaged endothelium will slow transfer into the alveolar gas and cause residual effects after clearance of bubbles. Air bubbles persist for a mean of 24.5 to 43 minutes after infusions of air at 0.1 to 0.25 ml/kg/min for 15 minutes in dogs.

CO2 is absorbed more rapidly than air as it is 34 times more soluble in blood and therefore the time to clear bubbles will be much shorter. The lethal venous dose of CO2 is approximately five times that of air in dogs with an air LD50 of 5.1 ml/kg and CO2 LD50 of 25 ml/kg. In addition, dogs surviving a near fatal CO2 bolus recovered much more rapidly than those dogs that received a near-fatal bolus of air.

Intravascular gas may distribute along either a flow or a gravity gradient. As the patient was in lithotomy the legs may have provided a large reservoir of venous gas due to retrograde flow of gas into the lower limb veins. The patient was therefore maintained in lithotomy position for 30 minutes while administering 100% oxygen to promote absorption. The legs were slowly lowered while the heart was auscultated, however no further changes were heard and there were no changes in $P_{\text{ET}}\text{CO}_2$ or $\text{SaO}_2$.

This patient demonstrated several features of gas embolism: $P_{\text{ET}}\text{CO}_2$ was reduced and a characteristic change in cardiac sounds occurred. These features rapidly resolved with cessation of the inflow of gas. Further support or treatment was unnecessary. The
appearance of changed cardiac sounds however, means that the patient may have been close to the limit of physiological reserve. Caution is advised when using diathermy inside confined spaces in the body, particularly if the bubbles are not quickly cleared through the endoscope sheath.

REFERENCES


Complications of Hysteroscopy—Their Cause, Prevention, and Correction

Franklin D. Loffer, M.D.

Abstract

Complications of hysteroscopy occur more frequently in operative than in diagnostic cases. Problems related to uterine distension are common, usually preventable, and potentially extremely serious. Perforation of the uterus may occur during hysteroscopy but do not always cause significant problems. In procedures of high risk for perforation the use of mechanical energy is safer than either laser or electrical energy. Laparoscopy and ultrasonography have some limited use in facilitating operative hysteroscopic procedures. Most complications occur during the hysteroscopic surgical procedure. However some problems may not be apparent until the post operative period.

Complications of hysteroscopy may occur when contraindications are ignored, for example, when proper surgical techniques are not followed or equipment is used in an inappropriate fashion. They also may occur when the procedure has been performed correctly on well-chosen patients.

Complications are not common, and many large series report no serious problems. When community wide experience is reviewed, complication rates exceed those published by experts. Therefore it is difficult to discuss their true frequency, since most go unreported or, if reported, are included in case reports without reference to the number of similar cases done without difficulty.

When complications do occur, most arise during operative rather than diagnostic hysteroscopy. Certain aspects of the procedures are more likely to be associated with difficulties than others.

Anesthesia

A paracervical or intracervical block is commonly used during diagnostic hysteroscopy, although the surgery can be performed without anesthesia. Operative hysteroscopy may be done with local infiltration into the cervix and paracervical area, but patients commonly receive general or regional anesthesia. Hysteroscopy does not add any special risks to these anesthetic techniques except possibly the additive effect of the distending medium.

Failure to Accomplish Hysteroscopy

Inability to introduce the hysteroscope into the uterine cavity and to obtain an adequate view should be considered a complication. Failure to accomplish the procedure will occur in all large series regardless of
the expertise of the surgeon. As experience is gained, however, the problem diminishes.4

Complications Associated With Distending Media

Uterine distention for panoramic hysteroscopy is necessary for two reasons. First, it must create a cavity by overcoming the resistance of the uterine musculature. Second, it has to be of sufficient pressure to prevent bleeding into the distending medium, which can obscure visualization. Complications are associated primarily with intravasation of distending media. They may occur during both diagnostic and surgical hysteroscopies and result from excessive absorption or idiosyncratic reactions to the medium. Unfortunately, the perfect medium does not exist.

Carbon dioxide (CO₂) is the usual medium for diagnostic office hysteroscopy. It is clean and safe, but has the disadvantage in operative cases of creating bubbles that may obscure vision. In addition, its low viscosity makes uterine distention during surgical manipulation difficult because of leakage around the gaskets of the instruments.

Thirty-two percent dextran 70 (Hyskon; Kabl Pharmac, Piscataway, NJ) allows for good visualization since it is not miscible with blood. Because of its high viscosity, administration requires increased pressure, but leakage is seldom a problem. However, complications due to dextran 70 may be difficult to manage.

Low-viscosity fluids are the media of choice for most operative procedures because they are ideally suited for the continuous-flow hysteroscope. The most commonly used solutions are 5% or 10% dextrose and water, Ringer’s lactate, normal saline, and the urologic distending media 1.5% glycine, 3% sorbitol, and 2.7% sorbitol with 0.54% mannitol. A 5% mannitol solution has also been suggested as a distending medium, but no reports of its use in hysteroscopy are available. Water should not be used since it causes hemolysis. Problems with intravasation of all these media have been recognized by urologists for over 40 years, but only more recently by gynecologists, and are well summarized elsewhere.5

Intrauterine Pressure

Three factors affect intrauterine pressure when creating uterine distention: the pressure of the infusion source forcing the medium through the tubing and hysteroscope into the uterus, the rate at which the medium flows into the uterus to equalize the pressure with the infusion source, and the rate at which the medium escapes from the uterus and must be replaced to maintain intrauterine pressure. Infusion pressure may be created by a hand-held syringe for dextran 70 and low-viscosity fluids; by mechanical insufflators for CO₂, dextran 70, and low-viscosity fluids; and by gravity for low-viscosity fluids. Transmission of this infusion pressure into intrauterine pressure is limited by the rate of flow of the distending medium. The rate at which a medium can be delivered into the uterine cavity is determined by the viscosity of the medium and the diameter of the tubing and hysteroscope channels.6

Intrauterine pressure is decreased by the medium’s outflow, which is not replaced. The medium may be lost due to leakage around the cervix, the outflow from continuous-flow equipment, passage into the abdomen through the fallopian tubes, and intravasation. Its passage into the vascular system may cause serious complications.

Infusion pressures of approximately 60 to 75 mm Hg are generally more than sufficient for distention and result in intrauterine pressures of approximately 10 to 15 mm Hg less.7 True intrauterine pressures are not measured by any available insufflating systems. Even if this were possible, the hysteroscopist should use the least infusion pressure necessary to distend the uterus and prevent bleeding into the medium.8 Higher infusion pressures do not provide better visualization except when the diameter of the tube or instrument is too small or the viscosity of the medium is too high to allow an adequate flow rate at usual pressures. These exceptions apply to low-viscosity fluids used with a 5-mm diagnostic sheath and to dextran 70. For both media, once good visualization is obtained, the infusion pressure should be reduced to the lowest level that maintains visualization.

Intravasation

Intrauterine pressure is the single most important variable the surgeon can control to prevent intravasation. A value greater than the mean arterial pressure significantly increases the risk of intravasation.8 Other factors also must be considered, for example, hysteroscopic procedures that open vascular channels at the length of the surgery.

Intravasation can occur when high pressures are used even when the endometrial surface is intact. However, procedures such as resection of myomata the endometrium, lysis of intrauterine adhesions, a
Carbon Dioxide

Carbon dioxide is a very safe distending medium since it is rapidly absorbed into the blood and readily released during pulmonary ventilation.\textsuperscript{15} No other gas can be used safely for this purpose. Little potential risk exists from the intravasation of CO\textsubscript{2} if a maximum pressure of 100 mm of Hg and a maximum flow rate of 100 ml/minute are not exceeded. When CO\textsubscript{2} hysteroscopy is performed during pregnancy, the maximum pressure and flow rate should be reduced to 50 mm Hg and 60 ml/minute.\textsuperscript{16,17} Higher pressure and flow rate may cause a large volume to be intravasted, which may result in metabolic changes, embolization, and death.\textsuperscript{15} The metabolic changes that may occur from excessive CO\textsubscript{2} are an increase in partial pressure of CO\textsubscript{2} and a decrease in partial pressure of oxygen, which result in metabolic acidosis and cardiac irregularity.\textsuperscript{16-20} Embolization of CO\textsubscript{2} in small volumes is not dangerous. It occurs in 52\% of patients undergoing a hysteroscopy with the gas as distending medium.\textsuperscript{21} Intravasation is more frequent at instillation pressures of 60 to 120 mm of Hg (57.7\%) than when pressures are less than 60 mm Hg (14.7\%).

Despite the fact that thousands of hysteroscopies are performed with CO\textsubscript{2} without difficulty, significant complications have been reported.\textsuperscript{3,15,22,23} All of these events occurred with excessive pressure and/or flow rates. Most often, equipment was used that was not designed for hysteroscopy. In one woman the instrument, flow rate, and pressure were appropriate, but the equipment malfunctioned and delivered a higher flow rate and pressure.\textsuperscript{3} These potentially catastrophic problems are prevented by using correct instrumentation that is checked periodically for accuracy and proper functioning.

Treatment of excessive CO\textsubscript{2} intravasation consists of immediate cessation of hysteroscopy, ventilation of the patient, and pulmonary and vascular supportive measures. If significant embolization has occurred with accumulation of undissolved CO\textsubscript{2} in the right side of the heart, blood flow may be increased by turning the patient on her left side.

Another complication of CO\textsubscript{2} hysteroscopy is rupture of a blocked fallopian tube. In one report this was related to the excessive pressure.\textsuperscript{24} Hypothermia as occurs during laparoscopy\textsuperscript{25} would appear to be unlikely, since much smaller volumes of gas are used.

Dextran 70

Complications of dextran 70 intravasation are pulmonary edema, coagulopathies, and allergic reactions including anaphylaxis. Some reports suggest that the pulmonary edema is related to a direct toxic effect on the pulmonary vasculature.\textsuperscript{26-29} although no good evidence exists to support this. Authors who believe there is a direct toxic effect on the lungs do not clearly state the amount of dextran 70 that was retained by the patient, and a direct toxic effect has been challenged.\textsuperscript{30-32} Many surgeons believe the suggested noncardiogenic pulmonary edema is related to the osmotic properties of dextran 70.\textsuperscript{38-36} The agent is a potent plasma expander, and for every 100 millimeters infused, the plasma
volume is expanded by an additional 860 ml. The significance of this can be demonstrated by the fact that infusion of 350 ml of dextran 70 intravascularly in a 60-kg patient will essentially double her plasma volume.

Intravascular coagulopathies may be related to an idiosyncratic reaction to dextran 70, but are more likely related to the volume intravasated, since the agent’s anticlotting properties are related to the amount used. Anaphylactic reactions have been reported as well as minor allergic reactions manifested by skin changes.

Pulmonary and coagulopathy complications of dextran 70 are prevented by limiting intravasation with careful monitoring of the intake and output to assess the amount that is retained. The manufacturer states that 500 ml is the maximum amount that should be used. It also states that hysteroscopies should be limited to 45 minutes. This time limitation does not seem necessary as long as the amount retained by the patient is known. It is the amount intravasated through the damaged endometrium and myometrium rather than the amount of dextran 70 used that is important. Nevertheless, the recommendations are important, since when the suggested volume was exceeded, there was a 1.1% frequency of pulmonary edema and a 0.5% frequency of disseminated intravascular coagulation.

Another problem with this viscous material is not knowing the intrauterine pressure created, because a very high pressure is necessary to ensure an adequate flow. This may translate into very high uterine pressures. Once distention has been achieved with dextran 70, only minimal additional pressure is necessary to obtain adequate visualization.

Treatment of pulmonary edema resulting from dextran 70 intravasation is oxygen, ventilatory support, and attempted diuresis. Diuresis is difficult, as the agent’s half life is several days. Since coagulopathies very likely are in part dose related, prevention is by limiting the amount intravasated. It is theoretically possible to prevent serious allergic reactions with administration of a hapten inhibitor. Management is supportive until the problem has self-corrected, although epinephrine and possibly hydrocortisone or antihistamines have been suggested.

Low-Viscosity Fluids

Low-viscosity fluids are the most commonly used distending media for operative hysteroscopy because they are ideally suited for the continuous-flow hysteroscope. They must be electrolyte free when used with electrical instruments, or the electrical current will be dissipated away from the electrode, rendering it ineffective. Complications related to these agents are primarily those of excessive intravasation. When excessive amounts are retained, edema with or without pulmonary edema may occur. If the infusing medium is dextrose and water, glycine, or sorbitol, hypotension or hypo-osmolarity may occur, since they are not isotonic electrolyte solutions. The addition of mannitol to sorbitol may help prevent the problem but is not fully protective; 5% mannitol may be preferable.

If electrical equipment is not used, hypotension and hypoosmolarity can be prevented by distending with normal saline or Ringer’s lactate; however, pulmonary edema is still a potential problem with these media. Fluid overload occurred in 1.1% of patients undergoing the high-risk procedure of resection of submucous myomas. A rate of 0.34% in 1988 dropped to 0.14% in 1991 and returned to 0.20% in 1993 according to surveys of general gynecologists.

Minimal changes in serum electrolyte levels may result in inconsequential problems, and significant changes may result in catastrophic problems. It is not the hypotension per se that is serious, but the cerebral edema that occurs as the brain absorbs water in an attempt to become isosmotic with the remainder of the interstitial fluid and vascular system. Cerebral edema results in increased intracranial pressure. Subsequent herniation of the brain stem may result in death. Young women appear to be at greater risk for this event than postmenopausal women or men, perhaps because their endogenous progesterone inhibits the enzyme sodium-potassium adenosine triphosphatase. Excessive intravasation of glycine may lead to hyperammonemia encephalopathy, which causes transient blindness, muscle aches, and memory loss.

Some surgeons measure serum electrolytes routinely, but most do not consider this to be necessary. Excessive intravasation is prevented by using as little pressure as possible to create adequate distension, and by accurately monitoring intake and output.

When excessive intravasation is recognized during the procedure, treatment is to discontinue the current as soon as safely possible. If the problem is recognized until it has occurred, it should be treated as an emergency. Patients should be maintained on hyperventilation for this event than postmenopausal women or men, perhaps because their endogenous progesterone inhibits the enzyme sodium-potassium adenosine triphosphatase. Excessive intravasation of glycine may lead to hyperammonemia encephalopathy, which causes transient blindness, muscle aches, and memory loss.
Traumatic Injuries of the Uterine Cervix and Fundus

Traumatic injuries related to hysteroscopy are more common during operative than diagnostic procedures because more dilatation is necessary for inserting the larger-diameter operative hysteroscopes. These may be nuisance injuries, such as cervical mucosal lacerations from the tenaculum, or they may cause intraoperative or postoperative problems, such as partial uterine perforation. They may also limit the ability to complete the procedure when adequate distention cannot be achieved after a complete uterine perforation.

Cervical tearing by the tenaculum during dilatation is a common event without significant sequelae. It occurs most frequently with a single-tooth tenaculum. A Jacob's tenaculum offers a firmer grip and is less likely to pull free and result in injury to the cervical mucosa. Treatment is suturing if bleeding is brisk.

Laceration of the cervical canal and lower uterine segment may also occur during dilatation. It results primarily when dilatation is required to accommodate larger instruments such as the resectoscope. These lacerations can frequently be seen in the lateral margins of the canal. They very occasionally may cause postoperative bleeding, both immediate and delayed. Correction is generally not necessary, although heavy bleeding could be coagulated with a resectoscope electrode. More commonly they become a source for fluid intravasation. Some authors prefer to avoid lacerations by inserting Laminaria the night before surgery.

The cervix or uterus may be perforated during dilatation or insertion of the hysteroscope. This is a potential problem especially in an acutely anteflexed or retroflexed uterus and in women with a stenotic cervix. The incidence is not known but probably comparable to that associated with endometrial curettage, 4 to 13/1000 procedures. This complication is prevented by maintaining appropriate techniques for dilatation. Another preventive measure is to insert the scope under direct vision. This may be difficult with the resectoscope, however, because of its width and sharp end. An obturator may be used, and the visual obturator is especially helpful (Circon ACMI, Stamford, CT).

Generally, perforations even with the large dilators require no treatment. Partial perforation requires no corrective measures. Most full-thickness perforations are in the fundal area, and although no treatment is necessary, adequate uterine distention is usually not possible and the procedure cannot be continued. Laparoscopy can be performed if there is any question as to the location of the perforation or the amount of intraabdominal bleeding.

Uterine Perforation

Uterine perforation rates and laparotomies to manage bowel or urinary tract injuries have risen slightly from 1991 to 1993, even though the complexity of the procedures has changed little.
Poor visualization and lack of uterine distension increase the risks of uterine perforation during hysteroscopy. Although complications from perforation are more common with thermal energy sources, they may also occur when mechanical energy is used.\(^\text{81}\) Scissors may be used to transect polyps, enucleate small fibroids, and transect uterine septa, and when a perforation occurs, the pelvic viscera usually is not damaged since the immediate outflow of distending medium alerts the surgeon to the event.

The surgical procedure that carries a high chance of uterine perforation even with concomitant laparoscopic control is transection of lateral and fundal uterine adhesions. The complication occurs with a frequency of 2 to 3/100.\(^\text{82,83}\) The procedure generally must be discontinued since uterine distention cannot be maintained. Because it is so common, it is my belief that it is inappropriate to use thermal energy to lyse these adhesions. In addition to the risk of injury to pelvic viscera, thermal damage may occur to the surrounding endometrium, which is already compromised.

It is difficult to prevent perforation during lysis of adhesions. Concomitant laparoscopy offers some benefit and should be employed in most cases of lateral and fundal lesions. Ultrasound guidance is also helpful. Unless the perforation is lateral in the lower uterine segment where branches of the uterine artery might be transected, no correction is generally necessary. Unless the case is near completion, it has to be rescheduled in 2 to 3 months after the wound has healed.

The risk of a uterine perforation during septum transection would appear to be approximately 1/100 procedures.\(^\text{84}\) It can arise despite concomitant laparoscopy. In addition, the uterus or fallopian tube may be perforated during tubal cannulation. The risk appears to be small, occurring 4 (11%) times during cannulation of 36 tubes, with no complications reported.\(^\text{85}\)

**Intraoperative and Postoperative Bleeding**

Intraoperative bleeding is usually not a problem since the pressure of the distending medium overcomes the pressure of most open vessels. Occasionally a small artery may spurt blood during a fibroid resection, or if myometrium has been entered during a septum transection or lysis of intrauterine adhesions. These can be easily controlled by using 40 W of a modulated (coagulation) current delivered through the loop electrode.

According to surveys of gynecologists, intraoperative and postoperative bleeding and associated complications have increased progressively.\(^\text{63-45}\) In a review of the literature of endometrial destruction by ablation or resection, the rates were between 0.2% and 1.0%.\(^\text{86}\) The majority of these events occurred during endometrial resection with a resectoscope or when a dragging (touch) Nd:YAG laser technique was used.

Postoperative bleeding is most common during removal of myomas, and reportedly occurred in 2.2% of cases.\(^\text{43}\) It should not be a difficulty with rollerball ablation unless there is a partial perforation of the uterus or a laceration has occurred in the lower uterine segment, since no vascular channels are otherwise open. It may occur after transection of the vascular uterine septum if the transection is too anterior, posterior, or high in the uterine fundus, thus opening myometrial vessels. Similarly, bleeding after transection of uterine synechiae indicates that myometrium rather than scar tissue has been cut.

It is difficult to prevent bleeding during removal of sessile fibroids since large vessels are exposed when the fibroid is enucleated from its base. This risk can be diminished if the myometrium is not damaged. This is accomplished by resecting only the portion of the fibroid that is protruding into the uterine cavity. Avoiding bleeding from transection of septum and lysis of adhesions is based on careful techniques in an effort to identify the visual difference between scarring septum and normal myometrium. Lower uterine segment laceration during dilatation can be prevented by inserting Laminaria.

At the termination of virtually every operative hysteroscopy there is the initial appearance of brisk bleeding. This generally is bloody distending medium draining from the uterine cavity. In bloodier cases such as fibroid resection, it may continue for a short time until the uterus contracts, very much like a postpartum uterus, and brings the bleeding to an acceptable level. Occasionally it is helpful to inject dilute vasopressin solution 3 U in 10 ml saline into the cervix to hasten uterine contraction and stop the bleeding. Alternatives are inserting a pack containing vasopressin,\(^\text{87}\) a Foley catheter,\(^\text{88}\) or a balloon into the uterus.\(^\text{89}\)

In over 200 fibroid resections, I have had to use an intracervical tamponade in only 6. These were all in the first 47 cases and probably reflected anxiety and lack of appreciation that the uterus generally contracts to stop bleeding. None of these women required transfusion. Others reported a 3% transfusion rate and the
from the operator. Depth perception is difficult during hysteroscopy, and once the fiber or loop is out of sight, the depth to which it is penetrating cannot be determined easily. Perforation of the uterus and injury to pelvic organs are best prevented by not advancing the activated laser fiber or electrode away from the end of the telescope, and not resecting myomas below the level of the uterine cavity. Only a few exceptions to this rule exist. The special circumstances when the electrode or fiber may be advanced away from the end of the hysteroscope are during transection of a septum and when undercutting a piece of partially resected fibroid that is hanging loosely in the uterine cavity. This can be done safely since the electrode or laser fiber is advanced only for very short distances and is always in direct view as it enters the tissue.

It is not necessary to cut below the level of the uterine cavity to remove the intramural portion of the myoma, but it is necessary when removing lateral and fundal intrauterine adhesions. Because of the increased risk of perforation during adhesion removal, thermal energy source presents an increased danger that is not found when mechanical methods are used.

If a perforation occurs and any question exists that thermal energy may have damaged the pelvic viscera, laparoscopy should be undertaken to determine if there is any blanching on the serosa of the uterus. If this is identified, abdominal exploration should usually be the next step, since it is difficult to inspect all of the bowel laparoscopically to look for sites of injury. If an injury is identified, it should be resected with adequate margins, rather than oversewn.

**Instrument Breakage**

Intrauterine instrument breakage can occur, with separation of scissor tips and resectoscope loops. An effort must be made to try to retrieve the broken piece, and this may be time consuming and difficult. There are probably no risks to leaving the missing piece in the uterine cavity; in fact, the piece may spontaneously exit the uterine cavity. However, retrieval should be attempted to avoid the medicolegal risks of leaving a foreign body inside the patient.

**Concomitant Laparoscopy or Ultrasonography and Hysteroscopic Surgery**

Laparoscopy or ultrasonography has been recommended to help avoid complications and increase
the accuracy of the surgery. I do not believe that routine laparoscopy is either justified or necessary except when extensive lateral and fundal intrauterine adhesions exist, or when the external configuration of the uterus is not known in the case of septate uteri.

Use of the laparoscope during operative hysteroscopy gives a false sense of security since the uterus is generally not in the laparoscopist's view when the hysteroscopist is operating. This is because the uterus is tipped backward rather than elevated anteriorly out of the pelvis, and therefore is hidden behind bowel. For the laparoscopist to view the uterine surface, the hysteroscopist must anteflex the uterus, which generally makes additional intrauterine surgery at that time difficult or impossible. Laparoscopy does have a role in evaluating the external uterine surface if any questions arise as to whether a perforation with injury to pelvic viscera may have occurred.

Ultrasound is suggested as a better method than laparoscopy to assist the hysteroscopist. It has value in determining the external configuration of the uterus in cases of septum, determining the extent of an intramural fibroid, identifying normal endometrium in patients with Asherman syndrome, and locating a hematometra after ablation. In addition it can contribute to the safety of the procedure by demonstrating the closeness of the operating instruments to the uterine surface.

Infection

Infection is seldom a problem in diagnostic hysteroscopy and is not reported in many large series. In 4000 cases, most of which were diagnostic hysteroscopies, 8 (0.2%) infections were reported. All occurred in the first 1000 cases and all were mild except one that occurred after laparotomy. The equipment was not sterilized between these cases, but only washed and rinsed with 70% alcohol.

Operative hysteroscopy increases the risk of infection not only by opening tissue planes, which allows the introduction of pathogens, but because the extended length of these procedures requires the hysteroscope to be removed and replaced into the uterine cavity through the vagina on numerous occasions. Infections may arise as endometritis, parametritis, or pyometra. A review of endometrial ablation showed a risk of 0.3%, and a general survey of operative hysteroscopy identified a rate of 1.6%. The latter figure may have been elevated by the inexperience of many of the operators. A 2.0% infection rate was found in reviewing the published reports on fibroid resection. Infections were found in 0.5% of 850 operative hysteroscopies even though the women received postoperative prophylactic antibiotics. In performing over 274 endometrial ablation cases, 156 fibroid resections, and 44 myoma resections and ablations, I have not yet had a patient who developed infection.

The first step in preventing infections is proper cleaning, disinfecting, and sterilization of equipment. Routines similar to those used in laparoscopy are satisfactory. Prophylactic administration of antibiotics, although practiced by some, is not universally employed by hysteroscopists and does not necessarily provide protection against infection. It would appear, however, that patients with a history of pelvic inflammatory disease should receive prophylactic antibiotics.

This recommendation is based on a series of 700 patients, 200 of whom did not receive the agents. Four (2%) of the 200 had a history of pelvic inflammatory disease, and three of them developed severe postoperative infections, including tubo-ovarian abscess. In the second group of 500 women, 10 (2%) had a history of pelvic inflammatory disease. All received doxycycline 200 mg twice/day starting at the time of Laminaria insertion. None developed a subsequent infection.

Although no infection or other problems have been demonstrated clinically, contamination with particulate matter in insufflated gas can occur, and the use of filters has been recommended.

Infection after hysteroscopy should be managed in the standard fashion.

Nerve Injuries

Nerve injuries are a small but persistent problem in hysteroscopy, occurring 0.01% to 0.04% of patients. They also occur with other gynecologic procedures, usually the result of stretching of the sciatic or peroneal nerve. Recovery generally is complete although it may be prolonged and associated with pain.

Development of Hematometra

Hematometra after endometrial resection or ablation is not reported frequently. One report found that it occurred in 1.8% of patients. It caused cyclic pain with or without uterine bleeding between 2 and 1 months after the procedure. Fourteen of the 16 women...
were managed by cervical dilatation. Two required
resection of uterine synechiae to approach the
hematometra in the uterine fundus. Another report
identified a hematometra from cervical stenosis in 3
of 61 patients.112

A variation of hematometra was described in
women undergoing rollerball ablation who were or had
been previously sterilized.113 These patients experi-
cenced intermittent vaginal bleeding that was associ-
ated with severe cramping pain. All had marked
endometrial scarring at hysteroscopy, and unilateral or
bilateral swollen, blood-filled fallopian tubes that
appeared similar to early ectopic pregnancy. Symptoms
in most of these patients were alleviated by laparo-
scopic removal of the remaining proximal tube or
tubes.

A review of my 247 cases of endometrial abla-
tion demonstrated this postablation tubal steriliza-
tion syndrome in 4 women and a suspicion that it
existed in 3 others. Of interest, only one of the seven
women had Nd:YAG laser ablation and six had resec-
tion with rollerball ablation. In reviewing these find-
ings it is my opinion that better cornual destruction
was achieved with the Nd:YAG laser, since in-depth
destruction occurred at approximately the same time
surface changes were seen. Because of concern for the
thinness of the cornual area, destruction apparently
was inadequate most frequently in cases in which a
rollerball was used. This would have been caused
not only by inadequate application of the rollerball at
the cornua, but also by the fact that the rollerball
would have been touching tissue in its anterior, pos-
terior, and forward positions, thus effectively dimin-
ishing current density by two-thirds. I am now more
conscientious about thoroughly destroying the cornual
areas with the rollerball.

Creation of Iatrogenic Adenomyosis

The risk of creating iatrogenic adenomyosis may
be more common with the resection technique than with
the rollerball or Nd:YAG laser.114,115 One reason may
be that resection does not uniformly remove all of the
deeper-lying normal endometrium that is usually
destroyed by the Nd:YAG and rollerball. The orienta-
tion of the resected strips does not always allow
the pathologist to determine if the full thickness of the
endometrium has been resected. In such case, the
remaining endometrium may be covered in scarring
and appear as iatrogenic adenomyosis. Another theory
for the adenomyosis is the transport of viable endome-
trial debris into the myometrium by the vessels opened
at resection.115

Adenomyosis may precede the ablation, and this
is a matter of controversy. Whereas some patholo-
gists are comfortable making a diagnosis of adenom-
ysis from hysteroscopic resection chips, and a
clinical correlation appears to exist,116 others are unwilling
to do so since a maximum depth of only 5 mm is
obtained by resection.

Endometrial Cancer

Two concerns have been raised with regard to
carcinoma of the endometrium and hysteroscopic pro-
cedures. The first is spreading of endometrial cancer
cells during hysteroscopy. It is known that hysteros-
scopy even using CO₂ can spread endometrial cells
into the peritoneal cavity.117 It has been suggested this
may increase the FIGO staging from a 1 to III.118 The
viability of these cells and whether or not their pres-
ence would have any long-term effect can be debated.
It would, however, commit the patient to more aggres-
sive therapy.

I reviewed 34 patients in whom endometrial car-
cinoma was identified at diagnostic hysteroscopy.
Carbon dioxide only was used in 26 women. Four of
them were switched from CO₂ to a fluid medium
because of poor visualization, and four had only fluid
medium used. Positive cytology was found in two
women. One in whom glycine was used already had
ovarian spread. The other had moderately differenti-
ated tumor extending two-thirds of the way through
the endometrial surface; CO₂ was the distending
medium. Whether the positive cytology in these two
patients related to the hysteroscopy cannot be deter-
mined, but it would appear that the chance of this is
of low magnitude.

The other potential complication raise by detrac-
tors of endometrial ablation is the risk of obscuring the
early symptoms of bleeding from an endometrial car-
cinoma. Five patients were reported in whom carci-
noma of the endometrium developed after endometrial
ablation.119-123 An early diagnosis was made in all four.
However, in my opinion, none of these women was a
good candidate for endometrial ablation.

Four women were menopausal when the ablation
was done. One had hyperplasia without atypia that had
responded to progestin, but she was not given the
agents after the ablation.119 Endometrial cancer
Complications of Hysteroscopy

The second woman had adenomatous hyperplasia with focal architectural atypia but no cytologic atypia. She remained asymptomatic, and 1 year after ablation a predominantly grade 1 focal grade 2 carcinoma with greater than 50% myometrial invasion was found at a hysterectomy for urinary incontinence. The third patient was a morbidly obese diabetic who was 4 years postmenopausal at the time of ablation. Benign adenomatous hyperplasia had been found at dilatation and curettage (D&C) 2 years before, but a D&C 5 months before ablation revealed only an atrophic endometrium. She, too, did not receive progestins after ablation. The fourth patient had focally atypical endometrium at the time of ablation. Fourteen months later she was diagnosed with metastatic carcinoma of the endometrium. The one woman who was not menopausal was a 39-year-old chronic anovulator who had an endometrial ablation rather than cyclic progestins for dysfunctional bleeding. She did not receive postablation progestins.

Offering endometrial ablation to postmenopausal and anovulatory women should always be looked upon skeptically. The postmenopausal women described above manifested considerable endogenous estrogen effect, and two even suggested some endometrial atypia. The fifth patient probably could have been managed without surgery by cyclic progestins. All of these women were less than ideal candidates for the procedure, but once it was done, they should have received cyclic progestin therapy.

Endometrial cancer associated with endometrial hyperplasia was found at the time of endometrial resection. No malignancy remained in the hysterectomy specimen. A complete preoperative work-up should be able to avoid this potential problem in all but the most unusual case.

Intrauterine Adhesion Formation after Correctly Done Hysteroscopy

Complications of hysteroscopic surgery when taken in its broadest sense can occur when the procedure has been performed correctly and safely. Postoperative intrauterine adhesions are undesirable in women who seek to maintain their fertility. This is not a major problem after fibroid resection, having been reported in 6% of patients undergoing follow-up hysteroscopy. The removal of numerous fibroids or fibroids on opposing walls probably increases this risk. Although it would be theoretically possible to introduce a balloon or intrauterine device (IUD) into the uterine cavity after fibroid resection, the problem is infrequent enough that it seems more prudent to perform a repeat hysteroscopy in the office after the first spontaneous menses. If an adhesion is found, it can be easily lysed under direct vision. Consideration can also be given to administering oral estrogen to help reepithelize the raw surfaces. However, this was not found to be necessary after transection of uterine septum where normal endometrium will cover the surface in 2 months.

Recurrence of intrauterine synechiae is considerably more difficult to manage. The extent of adhesion formation depends on their location and the amount of uterine surface involved. When extensive adhesions are lysed, little normal endometrium remains to be reepithelized and the risk of recurrence is high. It is difficult to keep separate the walls of the lateral and fundal adhesions to allow reepithelialization. An effort can be made to separate the walls by inserting a non-copper, nonprogressive IUD for the short term, or an intrauterine balloon or Foley catheter. Most authors believe estrogen should be administered to these patients to facilitate endometrial regrowth. When the adhesions are limited to the upper cervical canal and lower uterine segment, IUDs are not necessary, and office dilatation for several weeks will prevent reformation.

The formation of scarring after a septum transection is seldom a problem, and an intrauterine stent is not necessary. These cut surfaces are avascular and do not heal together. Reepithelialization is rapid.

Difficulties With Pregnancies

No problems are expected after the uncomplicated removal of a fibroid or transection of a septum and fertility should be enhanced. However, pregnancy after intrauterine surgery may be unexpected or be associated with difficulties. Abnormal implantation resulting in a placenta accreta or a poor pregnancy outcome may occur in women who have had lysis of uterine synechiae. Abnormal implantation is caused by lack of normal endometrium on which the placenta can form a normal attachment. This is almost impossible to prevent. Correction consists of obstetric management similar to that when the disorder occurs spontaneously. Unplanned pregnancies may occur after endometrial ablation in patients who were not sterilized previously. Their frequency is reported to be 0.2%
1.6%\textsuperscript{12} but the true figure is probably much higher, since many women undergo hysteroscopic sterilization or use other forms of contraception. If a pregnancy occurs after ablation, an ectopic gestation should be ruled out. The woman who chooses to continue the pregnancy should be made aware of the fact that since the vascular supply to the uterine surface has been damaged by the endometrial surgery, a placental insufficiency-like syndrome could develop,\textsuperscript{13} as well as other serious placental problems.\textsuperscript{12,132}

Uterine rupture has been reported during pregnancy after a uterine perforation at hysteroscopy for septum transection for submucous myoma resection and during lysis of adhesions.\textsuperscript{129, 135-137} One of my patients experienced such an event at 28 weeks' gestation. It was in the left fundal area, at the site of a perforation that occurred during lysis of severe intrauterine adhesions.

Even though the tubal ostia are easily approached hysteroscopically, pregnancies commonly occur after most hysteroscopic sterilizations\textsuperscript{138} Only formed-in-place silicone plugs (Ovabloc System; Aphonion, Amsterdom, The Netherlands) have been effective in preventing pregnancies.\textsuperscript{139} Other ostial tubal plugs have not justified clinical trials. The primary reason that an electrical hysteroscopic sterilization techniques were abandoned was the high frequency of perforation and bowel injuries. However, a second reason makes any type of tubal sterilization that attempts to close the tube at the ostium unreliable, even if the depth of the destruction could be controlled; that is, the 1% ectopic pregnancy rate, with three-fourths of them being interstitial ectopic pregnancies.\textsuperscript{138}

\textbf{Death}

Fortunately, deaths related to hysteroscopy are infrequent, and many large series do not report any. The true rate is not known, since deaths may go unreported and the denominators are not generally given in published case reports. A rate of 1.7/10,000 cases has been reported.\textsuperscript{64}

\textbf{Summary}

If the contraindications to hysteroscopy are observed, complications should be kept at a minimum. The risk of fluid overload, especially in operative cases, is the single most common and critical complication. Accurate recording of fluid intake and outflow are absolutely essential. This and all other complications are most likely to arise in the hands of inexperienced and unsupervised surgeon.\textsuperscript{2,93}

\textbf{References}

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given four hours later. Thirteen hours after the ingestion the theophylline level was 31 µg/ml (170.5 µmol/l) and had fallen further to 23.2 µg/ml (128.8 µmol/l) at 14.5 hours. No further dose of antiemetic was required and she was discharged from hospital after psychiatric review at 36 hours.

Although this girl may have reached her peak plasma theophylline level at the time of administration of ondansetron, the serotonin antagonist promptly "switched off" her vomiting, allowing successful gut decontamination with activated charcoal. Despite the expense of this drug, our Pharmaceutical Advisory Committee has, on the basis of this case, approved the use of ondansetron for refractory vomiting following theophylline overdose. We believe that use of this drug warrants consideration under such circumstances.

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References

Endometrial ablation and air embolism

Dear Sir,

A 40-year-old woman weighing 80 kg presented for endometrial ablation. She was generally in good health and had had previous uncomplicated anaesthetics. Preoperative haemoglobin and electrolytes were normal.

She received temazepam 20 mg as premedication and was induced with fentanyl 100 µg, followed by a sleep dose of thiopentone 350 mg. Intubation was facilitated with vecuronium 7 mg. After intubation, anaesthesia was maintained with nitrous oxide, oxygen (FiO2 0.3) and isoflurane 0.8%. Monitoring consisted of ECG, noninvasive blood pressure, pulse oximetry and capnography.

During the course of the anaesthetic, her blood pressure was 120-130 mmHg systolic, pulse oximetry 98%, and endtidal CO2 32 mmHg. Endometrial ablation was performed with the use of "roller ball" electrosurgery and 1.5% glycine under pressure of 90-100 mmHg. She was placed in the lithotomy position with slight head-down tilt. Approximately 40 minutes after commencement of the operation, the capnograph showed an endtidal carbon dioxide level of 20 mmHg and pulse oximetry reading of 90%. However, a radial pulse was easily felt, and blood pressure was 120 mmHg. There was no change in ventilation parameters. Auscultation of the chest showed equal air entry, normal heart sounds, with no added sounds. Surgery was immediately ceased and a presumptive diagnosis of air embolus was made. Within approximately two minutes pulse oximetry and endtidal carbon dioxide readings returned to normal. It was calculated that she had absorbed 600 ml of glycine solution. The acute changes in oximetry and ETCO2 were verified on the trend mode of the Datex monitor. Inspection of the glycine bags and tubing showed no evidence of air. As the patient's clinical condition was stable and surgery was nearly finished, surgery was allowed to be completed. This took about five minutes.

Muscle relaxation was reversed with neostigmine and atropine. She developed laryngeal spasm on extubation, requiring re-intubation, but recovery was uneventful and she was discharged from hospital the following day. Postoperative electrolytes and haemoglobin were normal.

Endometrial ablation with the use of "roller ball" electrosurgery is a new surgical procedure in which air embolus is a rare but possible complication. It has been reported with the use of "loop diathermy" endometrial ablation. Anaesthetists should be alert to the possibility of air embolus in this procedure. Air could come from the glycine bag or tubing, but also from the "bubbles" produced by the diathermy in the glycine. The surgeon's comment during this case was that the bubbles generated by the diathermy were "very small". However, they are under pressure of 90-100 mmHg and would expand when in the venous system with a much lower pressure. It may also be argued that an acute absorption of glycine may have caused the changes in pulse oximetry and EtCO2.

ANDREW MICHAEL
Lyell McEwin Health Service,
Elizabeth Vale, S.A.

References

Use of a size 2 LMA to relieve life-threatening hypoxia in an adult with quinsy

Dear Sir,

One of the major advantages of the LMA is the rapid relief of hypoxia following failure to intubate where alternative airway techniques prove inadequate. We would like to report the uneventful use of a size 2
GAS EMBOLISM

CLAUS M. MUTH, M.D., AND ERIK S. SHANK, M.D.

GAS embolism, the entry of gas into vascular structures, is a largely iatrogenic clinical problem that can result in serious morbidity and even death. Since gas embolism can result from procedures performed in almost all clinical specialties (Table 1), it is important for all clinicians to be aware of this problem. In most cases, gas embolism is air embolism, although the medical use of other gases, such as carbon dioxide, nitrous oxide, and nitrogen, can also result in the condition. There are two broad categories of gas embolism, venous and arterial, which are distinguished by the mechanism of gas entry and the site where the emboli ultimately lodge.

VENOUS GAS EMBOLISM

Venous gas embolism occurs when gas enters the systemic venous system. The gas is transported to the lungs through the pulmonary arteries, causing interference with gas exchange, cardiac arrhythmias, pulmonary hypertension, right ventricular strain, and eventually cardiac failure. Physical preconditions for the entry of gas into the venous system are the incising of noncollapsed veins and the presence of subatmospheric pressure in these vessels. Noncollapsing veins include the epiploic veins, the emissary veins, and the dural venous sinuses. Air may enter these veins during neurosurgical operations, especially those performed with the patient in the sitting position. The veins of the throat, and in some cases the veins in the coagulated operative field, may also be entryways for air. Air may also enter veins through central venous and hemodialysis catheters and may enter the veins of the myometrium during pregnancy and after delivery.

Pathophysiology

The most frequent form of venous gas embolism is the insidious venous aeroembolism, in which a series of gas bubbles resembling a string of pearls enters the venous system. Rapid entry or large volumes of gas put a strain on the right ventricle because of the migration of the emboli to the pulmonary circulation. The pulmonary arterial pressure increases, and the increased resistance to right ventricular outflow causes diminished pulmonary venous return. Because of the diminished pulmonary venous return, there is decreased left ventricular preload, resulting in diminished cardiac output and, ultimately, systemic cardiovascular collapse. Tachyarrhythmias often develop, but bradycardias are possible as well. When large quantities of gas (over 50 ml) are injected abruptly, acute cor pulmonale, asystole, or both are likely to occur. The alteration in the resistance of the lung vessels and the mismatch between ventilation and perfusion cause intrapulmonary right-to-left shunting and increased alveolar dead space, leading to arterial hypoxia and hypercapnia.

Diagnosis

To diagnose venous gas embolism, the physician should assess the clinical findings. The so-called millwheel murmur, a splashing auscultatory sound due to the presence of gas in the cardiac chambers and great vessels, is often present and can be auscultated by a precordial or esophageal stethoscope. A decrease in the end-tidal carbon dioxide levels, as determined by capnometry, suggests a change in the relation between ventilation and perfusion due to the obstruction of the pulmonary arteries. Doppler ultrasonography is a sensitive and practical means of detecting intracardiac air, and it is often used during neurosurgical procedures, procedures with the patient in the sitting position, and other procedures that entail a high risk of gas embolism. An even more sensitive and definitive method for detecting intracardiac gas is transesophageal echocardiography, although it requires training in performance and interpretation (Fig. 1).

Treatment

When venous gas embolism is suspected, further entry of gas must be prevented. In certain cases, therapy with catecholamines is required, and, if necessary, aggressive cardiopulmonary resuscitation is performed. Adequate oxygenation is often possible only with an increase in the oxygen concentration of the inspired gas (up to 100 percent oxygen). Supplemental oxygen also reduces the size of the gas embolus...
### Medical Specialties with Documented Cases of Gas Embolism

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<tr>
<td>Vascular surgery</td>
<td>Entry of air during carotid endarterectomy</td>
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by increasing the gradient for the egress of nitrogen from the bubble.13 Rapid resuscitation with volume expansion is recommended to elevate venous pressure, thus preventing the continued entry of gas into the venous circulation.

Some authors recommend attempting to evacuate air from the right ventricle with the use of a central venous catheter (a multiorifice catheter may be more effective than one with a single lumen) or a pulmonary arterial catheter.2,14,15 It may be possible to aspirate about 50 percent of the entrained air from an appropriately placed right atrial catheter,2,14 but depending on the placement of the catheter and the position of the patient, a smaller effect is more likely.2,15 Hyperbaric oxygen therapy is not a first-line treatment but may be a useful adjunct in severe cases. It should certainly be considered if there is evidence of neurologic changes. In this case, it should be assumed that a paradoxical embolism is present.

### Paradoxical Embolism

A paradoxical embolism occurs when air or gas that has entered the venous circulation manages to enter the systemic arterial circulation and causes symptoms of end-artery obstruction. There are a number of mechanisms by which this can occur. One is the passage of gas across a patent foramen ovale into the systemic circulation. A patent foramen ovale, which is detectable in about 30 percent of the general population, makes possible right-to-left shunting of gas bubbles.16 If there is a patent foramen ovale and if the pressure in the right atrium exceeds the pressure in the left atrium, right-to-left flow through the foramen ovale may occur.17 Elevated pulmonary arterial pressure due to venous gas embolism may result in elevated right atrial pressure, making it possible for a bubble to be transported through a patent foramen. Furthermore, the decrease in left atrial pressure caused by controlled ventilation and the use of positive end-expiratory pressure may create a pressure gradient across the patent foramen ovale, favoring the passage of gas into the systemic circulation.2,5

In other situations, venous gas may enter the arterial circulation by overwhelming the mechanisms that normally prevent arterial gas embolism. Studies in animals suggest that either a large bolus of gas (20 ml or more) or small continuous amounts (11 ml per minute) introduced into the venous system may
Arterial gas embolism is caused by the entry of gas into the pulmonary veins or directly into the arteries of the systemic circulation. Gas may enter the arteries as a result of overexpansion of the lung by decompression barotrauma or as a result of paradoxical embolism. Any cardiac surgical operation that uses extracorporeal bypass may also cause arterial gas embolism.23 Even if only small amounts of gas enter the arterial system, the flow of gas bubbles into functional end arterics occludes these vessels. Although obstruction is possible in any artery, obstruction of either the coronary arteries or the nutritive arteries of the brain (cerebral arterial gas embolism) is especially serious and may be fatal because of the vulnerability of the heart and brain to short periods of hypoxia.24

Symptoms

The symptoms of cerebral arterial gas embolism develop suddenly. The clinical presentation, however, is determined by the absolute quantity of gas and the areas of the brain that are affected. Thus, there may be minor motor weakness and headache or moderate confusion; conversely, complete disorientation, hemiparesis, convulsions, loss of consciousness, and coma may occur.25 Asymmetry of the pupils, hemianopia, and impairment of the respiratory and circulatory centers (manifested as bradypnea, Cheyne-Stokes breathing, cardiac arrhythmias, and circulatory failure)25-26 are other well-known complications. In patients who have undergone surgical procedures that carry a risk of gas embolism, a delayed recovery from general anesthesia or a transitional stage of impaired consciousness may be a clue to the occurrence of cerebral arterial gas embolism. The diagnosis is not easy to establish in such patients, because complications of anesthesia, such as the central anticholinergic syndrome or the presence of residual anesthetic or muscle relaxant, can mimic mild cerebral arterial gas embolism.
protection after cerebral ischemia, the use of barbiturates for ischemic brain lesions has certain advantages. They reduce cerebral oxygen consumption, intracranial pressure, the production of free radicals, and the release of endogenous catecholamines. High doses of barbiturates depress respiration; ventilatory support must therefore be available when a patient is given barbiturates.

**Hyperbaric-Oxygen Therapy**

With hyperbaric-oxygen therapy, the patient breathes 100 percent oxygen at a pressure above that of the atmosphere at sea level. This therapy decreases the size of the gas bubble both by raising the ambient pressure (Fig. 3) and by causing systemic hyperoxia. An arterial partial pressure of oxygen greater than 2000 mm Hg is frequently achieved. The hyperoxia produces enormous diffusion gradients for oxygen into the bubble and for nitrogen out of the bubble. The hyperoxia also allows much larger quantities of oxygen to be dissolved in the plasma and increases the extent of oxygen diffusion in tissues. The improvements in the oxygen-carrying capacity of plasma and in the delivery of oxygen to tissues offset the embolic insult to the microvasculature.

Other benefits of hyperbaric oxygen have been proposed. It may help prevent cerebral edema by reducing the permeability of blood vessels while supporting the integrity of the blood-brain barrier. Furthermore, experiments have suggested that hyperbaric oxygen diminishes the adherence of leukocytes to damaged endothelium. These benefits suggest that all patients with clinical symptoms of arterial gas embolism should receive recompression treatment with hyperbaric oxygen. Although immediate recompression produces the best response, delayed treatment in a hyperbaric chamber may still be indicated to ameliorate the patient’s condition. Hyperbaric oxygen is the first-line treatment of choice for arterial gas embolism. Thus, as soon as cardiopulmonary stabilization has been achieved, the patient should be transferred to a hyperbaric chamber.

**Infusion Therapy**

There is some evidence that gas embolism may cause hemoconcentration, which increases blood viscosity and impairs the already compromised microcirculation. Therefore, normovolemia should be achieved to optimize the microcirculation. Hypovolemia is always tolerated less well than relative anemia. It is therefore acceptable to decrease the hematocrit, within certain limits. In animals, moderate hemodilution to a hematocrit of 30 percent reduces neurologic damage. Colloid solutions are preferable to crystalloid solutions for hemodilution, because the latter may promote cerebral edema. Hypertonic solutions (e.g., 7.5 percent sodium chloride solution) may become the first choice for volume replacement, but their use is still controversial and therefore cannot yet be recommended.

The goal of infusion therapy is normovolemia. Placement of a central venous catheter is strongly recommended to assess central venous pressure, which should be maintained at approximately 12 mm Hg. As a further method of ensuring adequate volume status, the urinary output should be monitored with a Foley catheter and maintained above 1 to 2 ml per kilogram of body weight per hour.

**Anticoagulant Therapy**

There is evidence that heparin may be beneficial in the treatment of gas embolism. Studies have shown that the clinical course of arterial gas embolism is less severe if the patient has been treated with heparin before the embolic event occurs. An argument against heparin therapy is the risk it entails of hemorrhage into the infarcted tissue. At present, the use of heparin for the short-term treatment of cerebral arterial gas embolism is not generally recommended.

**Corticosteroid Therapy**

The use of corticosteroids in patients with arterial gas embolism remains controversial. Some authors recommend treatment with corticosteroids to combat the brain edema that results from gas embolization in the cerebral arteries. Cerebral gas embolism initially induces the rapid development of cytotoxic brain edema, with diminished extracellular space and enlarged intracellular areas. This form of edema does not usually respond to corticosteroids. Some authors report that corticosteroids aggravate ischemic injury after occlusion of the vessels. Thus, since corticosteroids appear to offer no benefit in patients with cytotoxic edema and since these drugs may aggravate neuronal ischemic injury, we do not recommend them.
Lidocaine Therapy

Although the results of clinical studies of lidocaine for the treatment of arterial gas embolism are not yet available, studies in animals suggest that lidocaine may be beneficial. In animals given prophylactic doses of lidocaine, the depressant effects of gas embolism on somatosensory evoked potentials and the elevations in intracranial pressure caused by gas embolism were both reduced. In a clinical trial, lidocaine provided cerebral protection during cardiac surgery. Therefore, a strong argument can be made for administering lidocaine in a bolus dose of 1.5 mg per kilogram and maintaining a therapeutic concentration, with continuous intravenous administration in patients with severe arterial gas embolism. However, an overdose of lidocaine may cause central nervous system depression, cerebral convulsions, and bradyarrhythmias.

CONCLUSIONS

The entry of gas into the venous or arterial system is a risk in virtually all areas of clinical care. Venous emboli may lead to cardiovascular collapse or to paradoxical arterial emboli. Arterial emboli may occlude end arteries throughout the body and may cause serious morbidity or death if they occlude cardiac or cerebral vessels.

Regardless of the mechanism responsible for the embolism, rapid and aggressive treatment is essential to preserve life and function (Table 2). For venous gas embolism, the mainstays of treatment are the prevention of further entry of gas, volume expansion, the administration of 100 percent oxygen, often with ventilatory support; positive inotropic support; and cardiopulmonary resuscitation, if necessary. For arterial gas embolism, hyperbaric oxygen is the treatment of choice, as soon as cardiopulmonary stabilization has been achieved.

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Massive air embolism—a possible cause of death after operative hysteroscopy using a 32% dextran-70* pump

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Although hysteroscopy is considered a safe procedure, potentially fatal complications such as cardiac CO₂ embolism and anaphylactic reaction have been reported (1, 2). We report a fatal outcome after operative hysteroscopy using a 32% dextran-70 pump.

CASE REPORT

A 27-year-old woman was admitted for operative hysteroscopy because of intrauterine adhesions diagnosed by hysterosalpingogram. Her past medical history was unremarkable. The procedure was performed under epidural block. Thirty-two percent dextran-70 in dextrose (Hyskon; Pharmacia, Uppsala, Sweden) was administered through a pump (Quinones pump; Storz, Tuttingingen, Germany). Approximately 75 minutes after the beginning of the operation, a Hyskon bottle was replaced, apparently while the pump was still functioning. The patient became restless and coughed. Severe bradycardia appeared (50 beats/min), followed by electromechanical dissociation lasting 30 seconds, cyanosis, and respiratory arrest. A generalized rash was also noted and disappeared a few minutes later. The procedure was terminated. During the vigorous resuscitative efforts, crepitant femoral pulses were palpated, and when an arterial line was introduced blood with foam was obtained. Initial arterial blood gases were PCO₂, 77 mm Hg; PO₂, 16 mm Hg; pH 7.18. Massive air embolism was suspected by the attending team, and the patient was transferred to our institute for hyperbaric oxygen (HBO) therapy.

On arrival at our institute, 3 hours after the event the patient was in deep coma and artificially ventilated via an endotracheal tube. She was unresponsive to painful stimuli, with dilated pupils unreactive to light, and no tendon reflexes could be elicited. Systolic blood pressure was 80 mm Hg with intravenous dopamine drip. Chest x-ray revealed interstitial congestion compatible with pulmonary edema and ruled out pneumothorax. Arterial blood gases before initiation of HBO were (FIO₂, 1.0); PO₂, 40; PCO₂, 35; pH, 7.34; bicarbonate, 19; base excess, -6. Hyperbaric oxygen treatment was given in a multiplace hyperbaric chamber while the patient was ventilated with a gas mixture according to the following treatment protocol: [1] 30 minutes at 6 atmospheres of absolute (ATA), 50% O₂, 50% N₂. [2] Three cycles of 20 minutes at 2.8 ATA, 100% O₂. [3] 30 minutes slow decompression to 1.9 ATA, 100% O₂. [4] Two cycles of 60 minutes at 1.9 ATA, 100% O₂. During the treatment, a neurological examination revealed that the patient was in coma but had regained spontaneous breathing. Right hand movements were noted, both spontaneously and as a response to pain. The pupils were dilated and unreactive to light. General hypotonia was noted more on the left side. Biceps reflexes were weak bilaterally.
and the Achilles reflex was absent on the right side. Arterial blood gases were PO₂, 361; PCO₂, 42; pH, 7.23; bicarbonate, 18; base excess, −9. Throughout the 5-hour treatment the patient was hemodynamically unstable, and the pulmonary edema did not resolve. The patient was transferred to an intensive care facility, where she died 2 days later.

The main findings at autopsy were cerebral edema, hemorrhagic infarction of the left occipital lobe, epicardial and pleural effusions, pulmonary edema, and ascites. The heart was examined under immersion, and a few gas bubbles escaped from the left ventricle. Microscopic examination of the endometrium revealed inflammatory infiltrates, necrosis, and hemorrhage. The tubes and ovaries were normal. The pathologist’s diagnosis was anaphylactic shock.

DISCUSSION

The pump used during the procedure can generate a maximal pressure of 300 mm Hg, which is sufficient to push air or dextran into the endometrial vascular bed during operative hysteroscopy. The same mechanism of introducing gas under pressure into a body cavity resulting in gas embolism has been reported in laparoscopy and in orogenital sex during pregnancy (3). The resultant massive venous air embolism would explain the acute respiratory failure, the electromechanical dissociation, and the prolonged pulmonary edema, as large volumes of air are trapped in the right ventricle and in the pulmonary vasculature.

Massive venous air embolism can lead to arterial embolism in one of two ways. First, the increase in right atrial pressure may open a potentially patent foramen ovale, which has been reported in 20% to 35% of the general population. Unfortunately, the pathologist did not rule out this possibility in our patient. Second, large volumes of air in the pulmonary vascular bed may be transferred to the left atrium by means of physiological pulmonary shunts, or by overcoming a critical volume.

The crepitant pulses, the frothy blood obtained through the arterial line, the sudden neurological and cardiovascular collapse at the time the pump was functioning without Hyskon, and the initial favorable reaction to HBO all support the diagnosis of massive arterial air embolism. Generalized rash may also accompany air embolism.

Ahmed et al. (4) describe three cases of severe anaphylactic reaction associated with the use of 32% dextran 70 during hysteroscopy. In all three cases, the anaphylactic reaction occurred approximately 10 minutes after exposure to dextran. The authors emphasize that sensitization may occur even without previous exposure to dextran. According to the pathologist’s report in our case, the fact that shock occurred 75 minutes after exposure to dextran does not rule out the possibility that the cause of death was anaphylaxis.

The use of HBO for air embolism is well documented. The treatment is based on mechanical compression of the air bubbles to reduce their size (volume and pressure are inversely related). A reduction in the bubbles’ volume relieves the vascular obstruction and restores perfusion. Concurrently, HBO increases the gas gradient between the bubbles (mainly nitrogen) and the surrounding tissue (mainly oxygen) and hastens their resorption. Hyperoxygenation may oxygenate hypoxic neural tissue and by means of vasconstriction reduce brain edema, which may result from gas embolism.

Hysteroscopy is generally a safe and reliable diagnostic and therapeutic procedure. However, the gynecologist must be aware of the possible serious complications. Cardiac CO₂ embolism and anaphylactic complications have both been described (1, 2). The practicing gynecologist must realize that the female genital tract is a potential portal of entry of gas into the venous plexus that drains the uterus; gas embolism has been reported after orogenital sex (3), criminal and therapeutic abortions (5), hysteroscopy (1), and cesarean section (6). The pregnant woman is at a higher risk of this complication. However, the possibility must be borne in mind when treating the nonpregnant patient too.

SUMMARY

Although considered a safe procedure, operative hysteroscopy has been reported to result in serious and even fatal complications. A fatal outcome is described after operative hysteroscopy. The attending team made a diagnosis of massive air embolism. However, HBO therapy, which is the specific treatment for air embolism, yielded only transient improvement. The pathologist’s diagnosis on autopsy was anaphylaxis. These two complications must be borne in mind during the treatment.
procedure, and a contingency plan developed for dealing with them should they arise.

Key Words: Hysteroscopy, complications, dextran-70, air embolism, anaphylaxis, hyperbaric oxygenation.

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A Complication of Hysteroscopy: Air Embolism

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Hysteroscopy is an established gynecologic procedure that has been used for the past 20 yr as a diagnostic technique. It is also used therapeutically to remove foreign bodies and endometrial devices and more recently to treat Asherman's syndrome, excise uterine septa and submucosal myomas, and for endometrial ablation for intractable uterine bleeding. These newer applications use the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser or the urologic resectoscope. We present two cases of air embolism during operative hysteroscopy using the Nd:YAG laser and the resectoscope.

CASE REPORTS

Case 1. Patient 1 was a healthy 35-yr-old woman, ASA Physical Status 1, weighing 65 kg, scheduled for outpatient laser hysteroscopy for menorrhagia. General anesthesia was induced with thiopental, and succinylcholine was used to facilitate tracheal intubation. Anesthesia was maintained with isoflurane, nitrous oxide, and oxygen, and vecuronium was administered for relaxation. Intraoperative monitors included blood pressure cuff, ECG, pulse oximeter, temperature probe, and capnograph. The cervix was dilated, and a dual-channel hysteroscope with attached video camera was inserted into the endometrial cavity. The uterus was distended using lactated Ringer's solution in 5-l bags connected to clear y-type TUR tubing with gravity drainage. A 600-μm bare laser fiber was inserted through the accessory portal. The endometrium was ablated using a combination of "dragging touch" and "nontouch" techniques at powers of 50-65 watts. Intermittently, the uterine cavity was drained and redistended. Approximately 30 min into the case "excessive bubbling" was noted within the fluid distending the uterine cavity. Some bubbles had been noted in the tubing of the irrigation solution as bags were changed. The end-tidal CO₂ decreased from 34 to 22 mmHg. The gynecologist discontinued laser ablation and uterine irrigation. One hundred percent oxygen was administered. The patient remained hemodynamically stable; thus, patient position was not changed. The end-tidal CO₂ returned to normal within 3-4 min. A precordial doppler was added as an additional monitor and surgery resumed. Again, the end-tidal CO₂ decreased from 35 to 21 mmHg with a change in the doppler tones characteristic of air embolism. No bubbles had been noted in the tubing. The surgical procedure was discontinued and the lungs were ventilated with 100% oxygen. Again, there were no hemodynamic changes and the end-tidal CO₂ returned to normal within minutes without additional treatment. Neuromuscular blockade was reversed, the trachea was extubated, and the patient was taken to the recovery room awake and subsequently discharged without sequelae.

Case 2. Patient 2 was a 39-yr-old woman, ASA Physical Status 1, weighing 65 kg, scheduled for operative hysteroscopy using a resectoscope for symptomatic uterine fibroids. Following preanesthetic medication with midazolam, glycopyrrolate, d-tubocurarine, and droperidol, general anesthesia was induced with thiopental and tracheal intubation facilitated with succinylcholine. Anesthesia was maintained with isoflurane, oxygen, air, and fentanyl, and vecuronium was added for relaxation. Monitors used were a blood pressure cuff, ECG, pulse oximeter, capnograph, precordial doppler, temperature probe, nerve stimulator, and stethoscope. Following cervical dilation a resectoscope was inserted into the uterine cavity. Uterine distention was achieved with 1.5% glycine solution attached to tubing suspended above the patient. Glycine solution was released from the uterus intermittently via a port of the resectoscope controlled by the surgeon. A wire loop was placed in the endometrial cavity, and cutting and coagulation modes were used for resection and hemostasis.

After 30 min of surgery, while the uterus was being irrigated using a urologic bulb syringe, the doppler sounds suddenly increased, pulse oximeter readings decreased from 99% to 90%, end-tidal CO₂ decreased from 31 to 17 mmHg, and the blood pressure decreased from 120/80 to 90/60 mm Hg. Hysteroscopy was suspended and the lungs were ventilated with 100% oxygen. The end-tidal CO₂ had spontaneously increased to 25 mm Hg when an arterial blood gas was drawn and showed a pH = 7.50, PaCO₂ = 43, PaO₂ = 287, and hematocrit saturation = 99%. The patient's pulse oximeter readings, end-tidal CO₂, and blood pressure returned to baseline within 5 min without additional treatment and hysteroscopy was resumed. A central venous catheter was inserted following an increase in peak inspiratory pressures from 24 to 40 cm water and concern about both intravascular fluid absorption and further air emboli. No air was aspirated nor were other signs of air embolism noted. The initial central venous pressure was 25 mm Hg and plasma sodium was 121 mEq/l, indicating a dilutional hyponatremia and hyperkalemia. Treatment was initiated with 10 mg iv furosemide, resulting in a diuresis of approximately 2 l over the next 2 h. The operative hysteroscopy portion of the surgery lasted for 90 min and was followed by a laparotomy for myomectomy, with total surgical time of 150 min. At completion of surgery neuromuscular blockade was reversed and the patient's trachea was extubated without incident in the operating room. The patient was discharged home 2 days later without sequelae.

DISCUSSION

Complications of hysteroscopy result primarily from the media used for distending the uterus. The distending medium for hysteroscopy done as an office procedure is CO₂, although small infusions of dextran 70 are sometimes used to irrigate out blood, mucus, smoke, and de-
CASE REPORTS

Siegler and Valle warned that intrauterine gas pressures should not exceed 200 mmHg and that CO₂ flow should not exceed 100 ml/min at standard temperature and pressure to avoid air embolus. During operative hysteroscopy a liquid distending medium is used. Uterine distention is achieved by gravity flow or manual pumping of the liquid into the uterus with outflow controlled by an outflow catheter, leakage around the laser or resectoscope, or removal of the instrument from the cervix.¹⁻²

With either the Nd:YAG laser or resectoscope, endometrial blood vessels are disrupted and bleeding occurs. A high distending pressure tamponades blood vessels and reduces blood loss.¹⁻² However, fluid absorption occurs via the raw surface of severed venous channels.³⁻⁵

The possibility of gas embolization from gas under pressure and a denuded endometrium was reported by Loffer² and Baggish and Baltoyannis.² They noted that the use of a coaxial quartz fiber with sapphire tip on the Nd:YAG laser required a gas or liquid coolant transmitted in a sheath to the fiber tip and that introduction of a gas into the distended uterus could pose a risk of embolism. Baggish and Daniell⁶ recently reported two deaths from gaseous emboli and cardiovascular collapse in Nd:YAG laser operative hysteroscopies using such sheathed coaxial fibers and sapphire tips cooled with nitrogen and air. Prior to introduction of sapphire tips in 1985, however, bare fibers were used that required no cooling mechanism, and these remain in use.

We report two more cases of air emboli. For laser hysteroscopy our gynecologists use the bare fiber requiring no coolant instead of the coaxial sapphire tip. One possible explanation for our cases is air in the irrigation solution entering open venous sinuses under pressure. Another possible explanation is the venous absorption of some of the bubbles from vaporization of tissue. Gas bubbles, endometrial fragments, blood, and debris occur with laser vaporization and resectoscope coagulation of endometrial tissue and are evacuated from the uterus by the irrigant.²⁻⁴ These bubbles may contain particulates, CO₂, carbon monoxide, and other products of combustion.⁸

Although they have been observed to wash out of the uterus, it merits investigation whether these bubbles under pressure can pass into the disrupted vasculature of the distended uterus without immediately dissolving in the blood.

Our precautions and recommendations for operative hysteroscopy therefore now include continuous precordial doppler monitoring in addition to end-tidal CO₂ monitoring and pulse oximetry. We do not recommend routine insertion of central venous catheters, but in the event of a suspected embolus not immediately resolving on halting surgery, insertion of such a catheter should be considered along with repositioning the patient in left lateral decubitus position. We also avoid nitrous oxide to prevent enlarging an occult air embolus.¹⁰ Special attention is paid to complete evacuation of air from the irrigation fluid and tubing. Finally, prospective studies using intraoperative transesophageal echocardiography or precordial doppler ultrasound in cases of operative hysteroscopy would be helpful to clarify the risk of gas embolization during this procedure.

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Air embolism during transcervical resection of endometrium

Sir,—Dr Ralf Baumann and colleagues in their recent paper [1] attempted to reduce transtubal absorption by combining laparoscopic tubal occlusion (using the newly developed procedure of transcervical resection) and transcervical resection of the endometrium from systemic veins in the lateral pelvic wall. Over the next four minutes the patient's oxygen saturation fell from 97% to 84% and her pulse rate rose from 72 to 110 beats/min, consistent with air embolism. Her blood pressure was unchanged. The head down position was reversed and positive pressure ventilation started with 100% oxygen. The oxygen saturation returned to normal within 10 minutes and the patient made a full recovery.

Air embolism can occur during surgery whenever a vein is open and the air pressure exceeds venous pressure. This can be the result of a rise in air pressure, such as occurs during insertion of a central venous catheter or by causing mechanical pressure on the vein caused by raising the operative site above the level of the heart, which is a particular risk when the patient is breathing spontaneously. Air emboli have been reported to occur during neurosurgery [2] and less commonly during caesarean section [3] and transcervical resection of the prostate.

We present these data to warn others embarking on the newly developed procedure of transcervical resection of the endometrium that an anaesthetic technique employing positive pressure ventilation may be preferred. Our experience also suggests that patients should not be nursed in a head down position after operation.

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