Ph.D., Director, Department of Anesthesiology, University Hospitals of Cleveland and Professor and Chairman, Department of Anesthesiology, Case Western Reserve University School of Medicine. The authors also are indebted to Mssrs. Joseph Collins and James Wentzel of the Cuyahoga County Coroner's Photography Department for preparation of figures 1 and 2.

References

1. Zumwalt T: Endometrial ablation, Advances in Nd:YAG Laser Surgery. Edited by Joffe SN, Oguro Y. New York, Springer Verlag, 1988, pp 192–199
2. Goldrath MH: Hysteroscopic laser surgery, Basic and Advanced Laser Surgery in Gynecology. Edited by Baggish MS. Norwalk, Ct., Appleton-Century-Croft, 1985, pp 357–372
3. Lomano JM: Dragging technique *versus* blanching technique for endometrial ablation with the Nd:YAG laser in the treatment of chronic menorrhagia. Am J Obstet Gynecol 159:152–155, 1988
4. Loffer FD: Hysteroscopic endometrial ablation with the Nd:YAG laser using a nontouch technique. Obstet Gynecol 69:679–682, 1987
5. Baggish MS: New laser hysteroscope for Neodymium-YAG endometrial ablation. Lasers Surg Med 8:99–103, 1988
6. Baggish MS, Daniell JF: Death caused by air embolism associated with neodymium:yttrium-aluminum-garnet laser surgery and artificial sapphire tips. Am J Obstet Gynecol 161:877–888, 1989
7. Joffe SN, Applications in gastrointestinal bleeding, Lasers in General Surgery, Edited by Joffe SN. Williams and Wilkins, Baltimore, 1989, pp 173–183

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Hypercapnia During Laser Arthroscopy of the Knee

JOHN G. GOODE, M.D.,* ROBERT Y. GUMNIT, M.D.,† WARREN D. CAREL, M.D.,‡
MICHAEL MCKENNA, B.S.N., R.N.§

Surgical arthroscopy of the knee is conventionally done with surgical instruments in a fluid medium. After testing in animal and human models, laser arthroscopy of the human knee in a gas medium was described as early as 1983.[1] To the best of our knowledge, hypercapnia associated with laser arthroscopy of the knee has not previously been reported.

Case Reports

Case 1

An obese 35-yr-old, 82-kg woman with the diagnosis of internal derangement of the knee presented for surgical arthroscopy. Anesthesia was induced with a combination of fentanyl, thiopental, and succinylcholine. Isoflurane and vecuronium were used in conjunction with nitrous oxide for maintenance of anesthesia. Thirty minutes after the initiation of CO_2 insufflation and during arthroscopy tachycardia, hypertension and increased end-tidal carbon dioxide tension (ET_{CO_2}) from 29 to 76 mmHg (measured with a Nellcor Multi-Function Monitor) developed over 3–4 min. The patient's lungs initially were being ventilated mechanically *via* an endotracheal tube at a minute ventilation of 6.4 l/min (tidal volume = 800 ml, respiratory rate = 8). Increased minute ventilation first mechanically and then manually to 20 l/min (tidal volume = 1000 ml, respiratory rate = 20) only decreased the ET_{CO_2} to 58 mmHg.

The abdomen was noted to be acutely distended and the peak inspiratory pressure increased to greater than 60 cm H_2O. Delivery of 100% O_2 increased the O_2 saturation from 95 to 99%. A nasogastric tube did not relieve the abdominal distention. The ET_{CO_2} remained increased until CO2 insufflation ceased at which time the ET_{CO_2} tension returned to normal over approximately 15 min. The abdominal distention resolved over the same time period and retrospectively was probably secondary to a pneumoperitoneum. The trachea was extubated and the patient had an uneventful postoperative course.

Case 2

A 41-yr- old, 55-kg woman presented for surgical arthroscopy of the knee. She had been healthy previously except for a history of mitral valve prolapse. Anesthetic management was similar to that of case 1. Twenty minutes after initiation of CO_2 insufflation and during arthroscopy, hypertension and tachycardia developed, associated with marked generalized subcutaneous emphysema and increase of the ET_{CO_2} from 30 to 90 mmHg over 3–4 min. This patient's lungs were similarly being ventilated mechanically *via* an endotracheal tube at a minute ventilation of 5.6 l/min (tidal volume = 700 ml, respiratory rate = 8, peak inflating pressure = 20 cm H_2O). Increasing the minute ventilation first mechanically and then manually to 15 l/min (tidal volume = 600 ml, respiratory rate = 25) only minimally decreased the

* Staff Anesthesiologist, Mt. Sinai Hospital, Philadelphia, Pennsylvania, and Clinical Assistant Professor of Anesthesia, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.

† Staff Anesthesiologist, Mt. Sinai Hospital, Philadelphia, Pennsylvania, and Clinical Assistant Professor of Anesthesia, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.

‡ Chairman, Department of Anesthesia, Mt. Sinai Hospital, Philadelphia, Pennsylvania, and Clinical Assistant Professor of Anesthesia, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.

§ Operating Staff Nurse and Laser Safety Officer, Mt. Sinai Hospital, Philadelphia, Pennsylvania.

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Address reprint requests to Dr. Goode: Department of Anesthesia, The Graduate Hospital, One Graduate Plaza, Philadelphia, Pennsylvania 19146.

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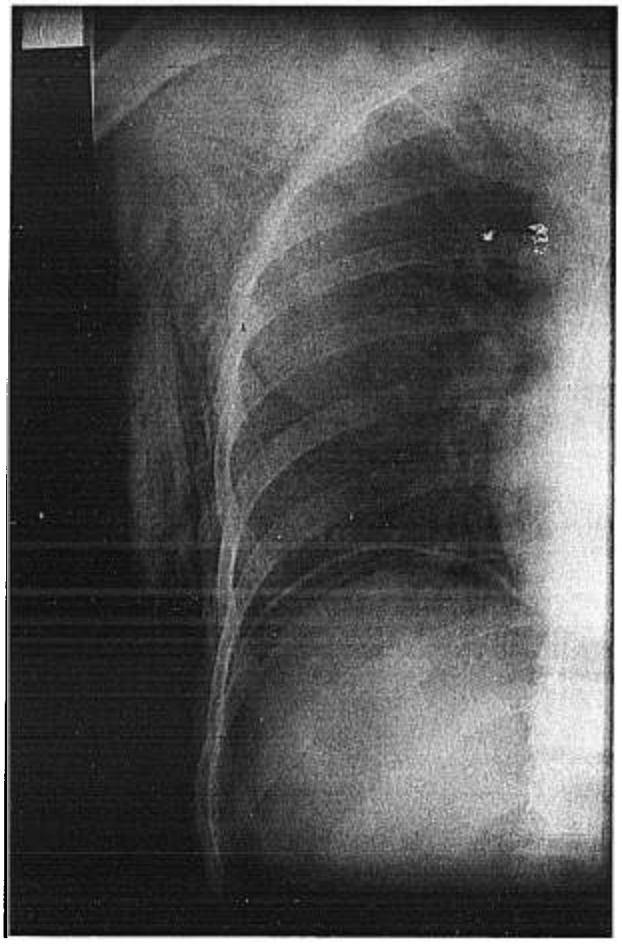

FIG. 1. CXR showing subcutaneous emphysema along lateral chest wall and pectoralis muscle as well as free air under the right hemidiaphragm.

ET_{CO_2}, whereas the peak inspiratory pressure increased to greater than 60 cm H_2O. The O_2 saturation remained at 99%. A chest x-ray taken while the trachea was still intubated showed generalized massive subcutaneous emphysema and a pneumoperitoneum (fig. 1). The ET_{CO_2} remained increased until approximately 15 min after CO_2 insufflation ceased. The trachea was extubated, and the patient recovered uneventfully. Subcutaneous emphysema slowly resolved over the next several hours.

DISCUSSION

The knee joint has been distended with carbon dioxide, nitrogen or helium during arthroscopy with the CO_2 laser. The gas insufflator, which is used at our hospital during CO_2 laser arthroscopy, is designed to deliver CO_2 at a maximum pressure of 2 pounds per square inch (103 mmHg).¶

The incidence of localized subcutaneous emphysema after laser arthroscopy of the knee has been reported as high as 100%.[2] Extension of subcutaneous emphysema has been reported only during shoulder arthroscopy. Smith and co-workers have reported one case of subcutaneous emphysema of the neck and scrotum and two cases of transient pneumothoraces when helium was used for this procedure.[2]

In 1983, Whipple and others described development of varying degrees of subcutaneous emphysema using nitrogen or CO_2 during laser knee arthroscopy of amputation specimens if the infusion pressure of the gas used to distend the joint exceeded 100 mmHg or if surgical instruments were frequently exchanged.[1] Furthermore, in 1985 Whipple and co-workers reported that in clinical trials of nitrogen for knee arthroscopy, gas that dissected into the subcutaneous tissues remained for several days.[3] Since laser arthroscopy provides immediate hemostasis, a tourniquet is not used at our institution for laser arthroscopy of the knee. In contrast, a tourniquet was routinely used by Smith and co-workers** during their performance of 325 laser arthroscopies of the knee.

Prior to experiencing the above complications we had performed 51 knee arthroscopies using the CO_2 laser in a CO_2 insufflated joint without complications. The only recent change in our technique was insufflation of CO_2 during introduction of the insufflation cannula.

We assume that the above complications of subcutaneous emphysema and pneumoperitoneum were secondary to dissection of CO_2 from the knee joint into surrounding tissues. The increased heart rate and blood pressure were a consequence of hypercapnia. We believe that the hypercapnia was secondary to hypoventilation as well as increased CO_2 delivery. The hypoventilation was caused by decreased pulmonary compliance secondary to increased abdominal pressure. Because the rate of rise of the ET_{CO_2} was greater than the 3–6 mmHg/minute expected with apnea[4] and the ET_{CO_2} remained increased despite increased minute ventilation until CO_2 insufflation ceased, increased CO_2 delivery must have contributed significantly to the increased ET_{CO_2}. Furthermore, two subsequent patients developed hypercapnia and subcutaneous emphysema of the leg, abdomen, and thorax during laser arthroscopy without abdominal distention or increase in peak inspiratory pressure. In each case the minute ventilation had to be increased by approximately 50% to decrease ET_{CO_2} to the baseline levels. These two cases provide evidence for increased CO_2 delivery as the etiology of the increased ET_{CO_2}.

We have reviewed our protocol for CO_2 laser arthroscopy and recommend the following measures:

¶ Instruction Manual: Orthopedic gas insufflator IN-2. Directed Energy Inc., Pfizer Laser Systems, October, 1988, p 1.

** Smith CF: Personal communication.

1) routine tourniquet use
2) avoidance of insufflation during entry of the joint (may lead to dissection of tissue planes)
3) close monitoring of the ET_{CO_2} tension
4) intraoperative assessment of the thigh for the presence of subcutaneous emphysema

In conclusion, laser arthroscopy of the knee, despite having possible advantages, can result in serious complications. Our cases demonstrate that it is possible for gas to dissect not only from the shoulder joint but also from the knee joint, producing hypercapnia, subcutaneous emphysema, and pneumoperitoneum.

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References

1. Whipple TL, Caspari RB, Myers JF: Laser energy in arthroscopic meniscectomy. Orthopedics 6:1165–1169, 1983
2. Smith CF, Johansen WE, Vangsness CT, Sutter LV, Marshall GJ: The carbon dioxide laser: A potential tool for orthopedic surgery. Clinical Orthopaedics and Related Research 242:43–50, 1989
3. Whipple TL, Caspari RB, Myers JF: Arthroscopic laser meniscectomy in a gas medium. Arthroscopy 1:2–7, 1985
4. Nunn JF: Applied Respiratory Physiology. London, Butterworths, 1977, pp 358–359

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Epidural Injection of a Phenol-containing Ranitidine Preparation

JOHN P. MCGUINNESS, M.D.,* KIMBERLY K. CANTEES, M.D.†

As the popularity of a continuous epidural infusion for postoperative analgesia has increased, so too have the reports of accidental administration of unintended drugs into the epidural space. A case is presented here in which a ranitidine preparation (Zantac, Glaxo) was inadvertently infused into the epidural space. Although the patient was unaffected, the potential for neurologic damage certainly is present since the ranitidine hydrochloride solution is prepared with phenol as a preservative.

Case Report

A 36-yr-old woman (weight, 64 kg; height 160 cm; ASA physical status 2) was scheduled for a right dismembered pyeloplasty. Her medical history was remarkable for a 28 pack year smoking history as well as a suspected mitral valve prolapse. Admission laboratory data were within normal limits. Prior to her arrival in the operating room, she received 10 mg diazepam by mouth as well as 30 ml clear antacid (Bicitra).

Prior to induction of general anesthesia, an epidural catheter was inserted at the L3–L4 interspace with an 18-G Touhy-Schliff needle and a loss-of-resistance technique. Proper positioning of the catheter was verified with a test dose of 3 ml 2% lidocaine with 15 μg epinephrine. General anesthesia was induced with thiopental and intubation was facilitated with vecuronium. Anesthesia was maintained with isoflurane, nitrous oxide, and oxygen as well as with sufentanil. The surgery proceeded uneventfully, and 1 h prior to the end of the procedure the patient received 100 μg fentanyl *via* the epidural catheter. At the end of the procedure the trachea was extubated and the patient was taken to the intensive care unit for recovery and observation.

On arrival to the intensive care unit an epidural fentanyl infusion in a concentration of 10 μg/ml was initiated at 60 μg/h *via* an infusion pump. The infusion pump was connected to the epidural catheter with an infusion set tubing with an injection port between the pump and the epidural catheter. The pump was labeled "epidural" and the distal end of the catheter was labeled "epidural catheter". The injection port in the connecting tubing was not marked. The patient was also to receive intravenous ranitidine administered *via* an infusion pump into a peripheral intravenous infusion. Neither this pump nor the intravenous tubing was marked to indicate a ranitidine infusion.

Six hours into the postoperative period, notification was received of the accidental administration of the ranitidine solution into the epidural catheter. The ranitidine solution was prepared from a 2-ml single dose vial; each milliliter of the solution contained 25 mg ranitidine (as the hydrochloride) as well as 0.96 mg monobasic potassium phosphate, 2.4 mg dibasic sodium phosphate, and 5 mg phenol. This solution has a *p*H of between 6.7 and 7.3.‡ For intravenous administration, it was diluted in 50 ml 5% dextrose and water. Approximately 30 ml of the 50-ml total volume had been administered when the error was noted. After notification, the epidural catheter was flushed with 10 ml normal saline, and the epidural fentanyl infusion was discontinued. The patient's subsequent analgesic regime included 2-mg boluses of intravenous morphine sulfate titrated to pain relief. The patient required a total of 8 mg over the next 9 h and was reported to be comfortable. This is a seemingly small amount of morphine considering the patient's incision. Immediately after the incident, the patient was free of neurologic symptoms and a neurologic examination at that time was normal, as were daily neurologic examinations performed for the next week. The patient was discharged home with no untoward sequelae.

* Chief, Anesthesia and Operative Service, Darnall Army Community Hospital, Fort Hood, Texas.

† Assistant Chief, Anesthesia and Operative Service, Darnall Army Community Hospital, Fort Hood, Texas.

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Address reprint requests to Dr. McGuinness: P.O. Box 086, Darnall Army Community Hospital, Fort Hood, Texas 76544.

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‡ Trissel LA: Handbook on Injectable Drugs, ed 5. Bethesda, American Society of Hospital Pharmacists, 1988, p 622