Carbon Dioxide Gas Arthrography for the Evaluation of Pediatric Hip Conditions: What is the Risk and Reliability?

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Background: Various pediatric conditions often necessitate a morphologic examination of the hip joint in infancy or childhood, and multiple imaging options have been employed to achieve this goal. Arthrography is one such modality. Different types of contrast media have been utilized and include pharmacologic contrast agents, air, and carbon dioxide. There are scattered reports of complications related to the typical various media used during arthrography. Some of the most concerning are related to gas emboli following the use of air or carbon dioxide. This study assesses the potential complications of carbon dioxide hip arthrography in a series of children over a 12-year period.

Methods: A retrospective review of the medical records of children between the ages of 0 and 3 years who underwent hip arthrography using carbon dioxide gas as the contrast medium was conducted. Outcome measures analyzed included volume of CO_2 injected, vital signs, and perioperative and postoperative end-tidal CO_2.

Results: Our study population was comprised of 118 hips in 90 children. We found no correlation between the volume of CO_2 injected and the patient's vital signs or end-tidal CO_2 at any point during the perioperative or postoperative period. None of the children exhibited any evidence for cardiopulmonary compromise or clinical signs of embolism.

Discussion: To our knowledge, there have been no large studies reporting on carbon dioxide arthrography and its potential complications. There were no gas embolisms and/or cardiopulmonary complications in our patients in the perioperative, postoperative, or 1-year follow-up period. Utilizing carbon dioxide gas as the contrast media for hip arthrography in children is safe and can help aid in the treatment of pediatric hip conditions.

Level of Evidence: Therapeutic Level IV.

Key Words: hip arthrography, carbon dioxide, pediatric hip, developmental dysplasia hip

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Hip arthrography is a common procedure performed for pediatric patients with developmental hip conditions and is utilized to better study the morphology of the pediatric hip. Different types of contrast agents have been used to better study the joint during both static and dynamic fluoroscopic examinations.[1–6] Typical media utilized are various chemical contrast agents, air, and carbon dioxide. Although relatively rare, cardiopulmonary complications have been reported throughout the orthopedic and anesthesia literature with regard to venous emboli, especially when air is used.[7–13]

Carbon dioxide has been used as a contrast agent for arthrography.[6,12] Carbon dioxide offers a higher solubility than air and therefore remains in circulation for a much shorter period of time.[12] As a contrast agent, it enhances an examiner's ability to better study the anatomy of a joint on a plain radiograph or during fluoroscopy.

To our knowledge, there have been no large studies reporting on carbon dioxide arthrography and its potential complications. We present our experience in a series of children who have undergone carbon dioxide hip arthrography at a tertiary pediatric center over a 12-year period.

METHODS

Approval was obtained from our Institutional Review Board before embarking on this study. A retrospective chart review was performed. Inclusion criteria were children aged 0 to 3 years who underwent hip arthrography using carbon dioxide as the contrast medium between the years 2000 and 2011 for developmental hip dysplasia. The senior author performed all procedures in an identical manner. All patients had a minimum of 1-year follow-up.

Exclusion criteria included those patients with < 1-year follow-up or patients with concomitant cardiopulmonary disease. Those patients who received carbon dioxide gas arthrograms followed by iothalamate meglumine (Conray; Mallinckrodt Inc., St Louis, MO) contrast agent were not excluded from the study as the effects of carbon dioxide could still be analyzed. Moreover, those undergoing concomitant procedures following hip arthrography were not excluded.

Data and outcome measures analyzed included patient age, sex, duration of procedure, diagnosis, procedure performed, amount of CO_2 injected, need for Conray and amount used, oxygen saturation at the time of arthrogram, pulse at the time of arthrogram, blood pressure at the time of arthrogram, end-tidal CO_2 ($ETCO_2$) at the time of arthrogram, $ETCO_2$ at the end of anesthesia, pulse in the postanesthesia care unit (PACU), blood pressure in PACU, oxygen saturation in PACU, respirations in PACU, pulse at time of discharge (TOD), blood pressure at TOD, oxygen saturation at TOD, respirations at TOD, and any intraoperative/postoperative complications.

Statistical analysis was performed using GraphPad Prism 6 (GraphPad Software Inc., La Jolla, CA) and included a linear regression analysis assessing the relationship between the amount of carbon dioxide injected at the time of hip arthrography and its effect on various vital signs used to monitor for an occurrence of a gas embolism.

TECHNIQUE

All patients were placed under general anesthesia and were attended to by a pediatric trained anesthesiologist. Utilizing a medial adductor approach, a 22-G spinal needle was inserted and an aspiration was performed to ensure avoidance of intravascular placement of the needle. This was carried out to ensure no carbon dioxide was injected directly into a vein or artery. Following this, a sterile 10-mL syringe was loaded with 10 mL of carbon dioxide gas, and a small amount (2 to 6 mL) of carbon dioxide gas was manually injected at ~0.5 mL/s rate per the attending surgeon (Fig. 1). If inadequate visualization occurred and/or further imaging necessitating intra-articular contrast was felt to be indicated following the arthrogram and fluoroscopic examination (ie, computed tomography), subsequent injection of a small amount (1 to 3 mL) of iothalamate meglumine (Conray; Mallinckrodt Inc.) was administered. Once the arthrogram was completed, concomitant procedures such as adductor tenotomy or spica cast application were performed as needed.

FIGURE 1. CO_2 arthrogram in an 18-month-old girl with developmental dysplasia of the hip.

RESULTS

Ninety patients with a total of 118 hips underwent carbon dioxide hip arthrography between January 2000 and July 2011. Seventy-four patients (82.22%) were female and 16 patients (17.78%) were male. Twenty-eight patients (31.11%) underwent bilateral arthrography. The average duration of the surgical procedure was 39.76 ± 11.49 minutes (range, 10 to 75 min). The average amount of carbon dioxide (CO_2) injected for the arthrogram was 3.61 ± 0.99 mL (range, 2 to 6 mL). Conray was used in 26 patients (37 hips). In 3 patients, Conray was used secondary to inadequate visualization following the CO_2 injection. The amount of Conray used ranged from 1 to 3 mL. There were no intraoperative or postoperative complications related to the arthrography, and there was no evidence for the occurrence of a gas embolism.

Oxygen saturation at the time of CO_2 arthrography averaged $99.74 \pm 0.51\%$ (range, 98% to 100%). Pulse at the time of CO_2 arthrography averaged 123.21 ± 15.32 bpm (range, 88 to 166 bpm). Blood pressure at the time of CO_2 arthrography averaged $90.89 \pm 10.95/46.56 \pm 9.50$ mm Hg. $ETCO_2$ at the time of CO_2 arthrography averaged 41.40 ± 4.94 mm Hg (range, 30 to 56 mm Hg) and at the end of anesthesia averaged 40.02 ± 4.02 mm Hg (range, 30 to 55 mm Hg).

In the postanesthesia care unit, pulse averaged 141.76 ± 21.97 bpm (range, 80 to 180 bpm), blood pressure averaged $101.28 \pm 16.14/59.02 \pm 16.05$ mm Hg, oxygen saturation averaged $99.58 \pm 0.81\%$ (range, 97% to 100%), and respirations averaged 26.78 ± 5.99 bpm (range, 16-50 bpm).

At the time of discharge, pulse averaged 133.26 ± 21.11 bpm (range, 73 to 175 bpm), blood pressure averaged $103.40 \pm 17.77/61.72 \pm 16.38$ mm Hg, oxygen saturation averaged $99.25 \pm 1.18\%$ (range, 95% to 100%), and respirations averaged 28.49 ± 6.50 bpm (range, 19 to 48 bpm).

At 1-year follow-up, all children in the study group were healthy and exhibited no signs of any cardiopulmonary conditions or complications that may have been attributed to the carbon dioxide hip arthrography.

Statistical analysis, through linear regression, concluded that there was no significant relationship between the amount of carbon dioxide injected and the change in the following vital signs: oxygen saturation, blood pressure, and end-tidal carbon dioxide during hip arthrography and throughout hospital admittance until discharge (*P*-value range: 0.30 to 0.98).

DISCUSSION

Hip arthrography is an integral tool in the treatment of pediatric hip disorders. The most common approaches for needle insertion into the hip joint are the medial and anterior approaches, although superior and lateral approaches have also been described.[1,2,7,14–18] Each technique, however, still undoubtedly depends on accurate needle placement into the hip joint, which can be challenging because of the joint's deep position within the body and the surrounding neurovascular structures that must be navigated. The pediatric hip is even more challenging because of the smaller anatomy, nonossified femoral heads, and the smaller joint space in which the needle must be placed. Moreover, altered anatomy resulting from a dislocated or subluxated hips in the majority of hip arthrograms performed in infants further adds to the difficulty in accurate placement of the needle.

To overcome these challenges, hip arthrography has been performed utilizing ultrasound, computed tomography (CT), and magnetic resonance guidance, however, fluoroscopy remains the gold standard.[19] Different techniques have been developed to increase the success of a fluoroscopic hip arthrogram. The traditional subjective feel during intracapsular penetration or free inflow and backflow of fluid or gas has been described, although high rates of failure have been reported.[3,18,19]

Despite the technique and approach chosen, a successful hip arthrography must also involve use of a contrast agent to adequately study the pediatric hip. With the use of pharmacologic contrast agents, enhanced visibility and an improved morphologic examination of the joint can be achieved. However, as with any substance injected into the body, complications can arise and include anaphylaxis, systemic effects related to cardiovascular and/or neurologic compromise, and other idiosyncratic reactions.[20] Local complications related to the arthrogram can also prove detrimental to the procedure and the patient. Extravasation of contrast material from a malpositioned needle may obscure the surrounding and pertinent anatomy with consequences lingering even after subsequent successful repositioning of the needle.[4,7–9] Increased systemic complications with contrast extravasation from extra-articular injection of contrast agents have also been reported.[4,7–9]

To decrease the complications associated with extracapsular extravasation of chemical contrast agents and the obscured picture that occurs secondarily, many practitioners have utilized air or carbon dioxide as contrast media. However, scattered reports of devastating complications related to air embolisms have been published in the orthopedic and anesthesia literature in connection with air contrast arthrography,[8,10–13,21] including one reported death resulting from an air embolus from a knee arthrogram.[5] Signs and symptoms of air embolism include global chest wheezing, bradycardia, hypotension, cyanosis, cardiac arrest, and even death.[9,12] The likelihood and severity of these effects depend on the volume and the rate with which the air is injected, with larger volumes and more rapid rate associated with more severe reactions. Because of the risks involved with using air as a contrast media for arthrography, carbon dioxide has been used as an alternative gas. The advantage lies with carbon dioxide's increased solubility in tissue compared with air, which allows for more rapid dispersion into the soft tissues and decreased time within the vascular circulation.[12]

There has been one reported case of a carbon dioxide embolism during hip arthrography.[12] Nishanian and Goudsouzian reported a case of a CO_2 gas embolus in an infant that occurred following hip arthrography.[12] In their report, a previously healthy 4-month-old patient with bilateral hip dislocations underwent bilateral hip arthrography. After an uneventful induction and intubation, the surgeon proceeded to inject 30 mL of carbon dioxide gas into each hip joint. Some gas had extravasated outside the hip joint into the iliopsoas sheath. The surgeon then continued with injection of diatrizoate, a radiocontrast agent, but also extravasated. The patient experienced several episodes of desaturation and decrease in $ETCO_2$ but following resuscitative measures, recovered without sequelae.[12] Despite this single case report, a carbon dioxide gas embolism appears to be a much less frequent occurrence compared with an air embolus. However, in contrast to air used in arthrography, carbon dioxide has been attributed to increased pain in some patients when injected into joint spaces. This has been attributed to the potential for CO_2 to decrease the pH in synovial fluid.[6]

In our series of patients undergoing carbon dioxide hip arthrography, no carbon dioxide emboli were found and cardiopulmonary function remained stable throughout the perioperative and postoperative periods. $ETCO_2$ and O_2 saturation throughout the procedures also remained stable. In addition, recovery room vital signs remained stable throughout all cases. The use of radio-opaque contrast agent iothalamate meglumine (Conray; Mallinckrodt Inc.) with some patients was largely because of the need for some patients to undergo CT scans of the hip to confirm appropriate reduction and position of the hips. In patients who required CT scan, the longer acting contrast agent iothalamate meglumine was used to better study the hip during CT. This was necessary because the carbon dioxide injected during the fluoroscopic arthrogram would have been reabsorbed by the time the patient reached the CT suite. We found that the additional time under anesthesia and in the CT suite did not adversely affect patient stability or outcome.

As observed in previous case reports involving gas embolism during arthrography, $ETCO_2$ was one of the main parameters that decreased in the immediate period of embolism formation and cardiopulmonary deterioration.[7,12] With the exception of 2 children in our study, $ETCO_2$ remained at normal values (35 to 45 mm Hg) and continued to be normal throughout the remainder of the surgery. The 2 children with $ETCO_2$ levels below normal at the time of carbon dioxide injection had preexisting $ETCO_2$ levels before carbon dioxide injection also below 35 mm Hg. Therefore, for those 2 patients, their values for low $ETCO_2$ levels were not likely attributable to embolism. In addition, the remaining vital signs were stable throughout the procedure for those 2 patients. All other patients had normal vitals and $ETCO_2$ levels at the time of carbon dioxide injection and remained stable throughout the perioperative, postoperative, and follow-up periods.

To our knowledge, there have been no large series or studies reporting on the results of carbon dioxide arthrography and its complications. The strength of our study is that it involves a large, consecutive series of patients treated by a single surgeon at a pediatric orthopedic center over a 12-year period. The weakness of our study is that it was a retrospective case series. Secondly, a power analysis was not performed; therefore, true statistical significance could not be obtained; however, it is noteworthy that no cardiopulmonary complications occurred in our large series of patients. Another weakness was that the true incidence of gas embolus during carbon dioxide arthrography could not be detected without more advanced monitoring during the procedure, such as intraoperative or postoperative echocardiography. Adding noninvasive monitoring adjuncts such as this may further help with early detection and ultimately initialization of potentially life-saving treatment. In our study, ultrasonography was not utilized; therefore, only data recorded by the anesthesiologist was analyzed and thus, only monitoring for symptomatic emboli was performed. Without advanced imaging, our study was dependent on the accuracy of their documentation. However, significant cardiopulmonary complications that would have resulted from a gas embolus would have been thoroughly documented and as none were found, our results were validated. Nevertheless, parents and guardians should be informed of the potential risk of gas embolism, both symptomatic and asymptomatic, during CO_2 arthrography.

Overall, hip arthrography remains a critical and valuable tool in the assessment and treatment of pediatric hip conditions and we believe that careful technique and a judicious choice of contrast agent will lead to reproducible, safe, and efficacious results. Our experience with CO_2 hip arthrography in children has yielded no significant complications and should be considered as a safe technique for evaluation of pediatric hip conditions.

REFERENCES

1. Lamdan R, Sadun A, Shamir MY. Near-fatal air embolus during arthrography of the hip in a baby aged four months. *J Bone Joint Surg Br*. 2007;89:240–241.
2. Lancaster SJ, Cummings RJ. Hip aspiration: verification of needle position by air arthrography. *J Pediatr Orthop*. 1987; 7:91–92.
3. Schwartz AM, Goldberg MJ. The medial adductor approach to arthrography of the hip in children. *Radiology*. 1979;132:483.
4. Severin E. Arthrography in congenital dislocation of the hip. *J Bone Joint Surg Am*. 1939;21:304–313.
5. Strife JL, Towbin R, Crawford A. Hip arthrography in infants and children: the inferomedial approach. *Radiology*. 1984;152:536.
6. Darling DB. *Hip Arthrography in Radiology of Infants and Children*. 3rd ed. Rochester, MN: Springfield; 1978.
7. Ozonoff BM. Controlled arthrography of the hip: a technique of fluoroscopic monitoring and recording. *Clin Orthop*. 1973; 93:260.
8. Schwartz AM, Goldberg MJ. Hip arthrography in children. *Skeletal Radiol*. 1978;3:155.
9. Yun AG, Reinker K. Accurate needle placement by the suction-bubble technique for hip arthrography. *J Pediatr Orthop*. 1999; 19:632–634.
10. Mitchell GP. Arthrography in congenital displacement of the hip. *J Bone Joint Surg Br*. 1963;45:88–95.
11. Goldman AB. Hip arthrography in infants and children. In: Frieberger RH, Kaye JJ, eds. *Arthrography*. New York, NY: Prentice Hall; 1979:217–236.
12. Hetherington RG. Venous air embolism during hip arthrography. *Anesth Analg*. 1989;69:264.
13. McCauley RG, Wunderlich BK, Zimbler S. Air embolism as a complication of hip arthrography. *Skeletal Radiol*. 1981;6:11–13.
14. Keidan I, Givon U, Berkenstadt H, et al. Venous air embolus during arthrography in a child: vital signs changes illustrated by the automated data recording system. *Paediatr Anaesth*. 2002;12: 362–364.
15. Kobayashi S, Takei T. Venous air embolism during knee arthrography. *Arch Orthop Trauma Surg*. 1991;110:311–313.
16. Kytta J, Tanskanen P, Randell T. Comparison of the effects of controlled ventilation with 100% oxygen, 50% oxygen in nitrogen, and 50% oxygen in nitrous oxide on responses to venous air embolism in pigs. *Br J Anaesth*. 1996;77:658–661.
17. Nishanian EV, Goudsouzian NG. Carbon dioxide embolism during hip arthrography in an infant. *Anesth Analg*. 1998;86:299–300.
18. Saha AK. Air embolism during anesthesia for arthrography in a child. *Anaesthesia*. 1976;31:1231–1233.
19. Freiberger RH, Killoran PG, Cardona G. Arthrography of the knee by double contrast method. *Am J Roentgenol*. 1966;97:736.
20. Durant TM, Long J, Oppenheimer MJ. Pulmonary (venous) air embolism. *Am Heart J*. 1947;33:269–281.
21. Munson ES, Merrick DC. Effect of nitrous oxide on venous air embolism. *Anesthesiology*. 1966;27:282.

