CERVICAL PLEXUS ANESTHESIA TO CONTROL DIAPHRAGMATIC EXCURSION DURING EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY

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In freely mobile kidneys, renal calculi are frequently driven across the shock beam by respiratory oscillations of the diaphragm. Diaphragmatic-related stone excursions are normally restricted to less than 1 cm, so that the stone remains within the confines of the shock wave beam at all phases of the respiratory cycle. This increases target-to-tissue shock wave energy. Disintegration is believed to be more effective if more shock waves are focused directly within the focal zone of the concretion. Anesthesia-free or "dry" nonimmersion electrohydraulic lithotripsy (Dornier MLF-5000, Munich, Germany) uses variable shock wave power intensities to allow for a reduction in anesthesia requirements. Under the higher power settings, increased fragmentation efficacy is possible. However, this comes at the expense of increasing pain and discomfort. Not uncommonly, the latter requires intravenous sedation and/or analgesia supplementation. Using the lower power setting, the MLF-5000 lithotripter yields approximately a 70% stone-free state, with a mean number of 2650 shocks at 20 kilovolts (kV) and only a 14% re-treatment rate.[1,2] This report describes the use of interscalene cervical plexus anesthesia to control diaphragmatic-related stone excursion and discusses its implications for patients undergoing extracorporeal shock wave lithotripsy (ESWL).

Case Report

A 45-year-old male (70 kg, 181 cm) presented to the hospital with a history of left flank pain and nephrolithiasis. An intravenous pyelogram (IVP) of the left kidney revealed a 10 mm midcalyceal stone localized at the left ureteropelvic junction (UPJ). During admission, an epidural, a general, and two intravenous anesthetics were administered uneventfully for ESWL (MLF-5000 apparatus). A total of 9498 shock waves at an average power of 22 kV was delivered with no apparent disintegration of the calculus. After considering the relative merits of previous anesthetic techniques, informed consent was obtained for interscalene cervical plexus block under monitored anesthesia care (MAC) with sedation. It was theorized that by controlling diaphragmatic-related stone excursion by indirect phrenic nerve block, i.e., cervical plexus anesthesia, the shock wave beam could be concentrated within a precise focal area (F2), resulting in fragmentation. Past medical history, physical examination, and laboratory results were unremarkable. Stone analysis revealed calcium monohydrate oxalate composition. Premedication included ranitidine 300 mg at bedtime and 2 hr preoperatively per os, morphine 10 mg and promethazine 6.25 mg intramuscularly (IM) 60 minutes prior to anesthesia induction. Intraoperative monitoring included electrocardiography (EKG), pulse oximetry (SaO_2), capnography ($ETCO_2$), temperature and continuous noninvasive blood pressure. A cervical plexus block was performed using a single paresthesia technique[3] using a Stimulex 22 gauge insulated mobile needle (Becton-Dickenson, Rutherford, NJ). An isolated nerve stimulator confirmed accurate needle placement.[4] A 2 mL test dose of methylparaben-free (MPF) 1.5% lidocaine with 1:200,000 epinephrine completely abolished twitch responses at 1.25 mA. A total of 10 mL of 1.5% lidocaine (MPF) with 1:200,000 epinephrine was injected slowly. Digital pressure was applied distal to the immobile needle[3] to facilitate anterograde diffusion into the cervical plexus. Anesthesia of the cervical plexus was evidenced by loss of sensation to pinprick over the C3-5 dermatomes, loss of shoulder abduction (C5-6) and phrenic nerve paralysis (C3-5). Computer-assisted biplanar fluoroscopy provided quantitative assessment of diaphragmatic paralysis and three-dimensional localization of the stone in a one-to-one image to concretion ratio. Blood pressure, SaO_2 and $ETCO_2$ using modified nasal prongs[5] were recorded every two minutes.

The initial stone excursion measured 44 mm breathing spontaneously, awake, in the supine position, with no intravenous sedation. After phrenic nerve block, stone excursion was reduced to 2.2 mm as measured by fluoroscopy. Baseline SaO_2 after IM premedication

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measured 98% on room air. SaO_2 decreased to a low of 92% 45 minutes into the case when incremental IV doses of midazolam 2.5 mg and meperidine 20 mg were given within a five minute interval. This brief desaturation occurred during minor discomfort in the prone position at higher power settings (24 kV). Supplemental oxygen (24%, 2L/min) through nasal prongs restored SaO_2 to 97%. $ETCO_2$ ranged consistently between 36 and 42 mm/Hg on 24% oxygen. A total of 2036 shock waves over 107 minutes were fired at an average power rating of 22 kV (range 18 to 24 kV). At conclusion of ESWL, fluoroscopy and kidney-ureter-bladder x-rays confirmed stone fragmentation and disintegration. Postoperatively, no pneumothorax or persistent diaphragmatic paresis was visualized on fluoroscopy. Discharge SaO_2 was 97% on room air after 60 minutes in recovery.

Discussion

Alternate techniques for controlling diaphragmatic-related stone excursion in water-immersion ESWL employ general anesthesia with controlled mandatory ventilation,[6,7] high frequency jet ventilation,[8,9] and high frequency conventional ventilation.[10] Under epidural anesthesia, IV midazolam has also been used to pharmacologically control diaphragmatic-related stone excursion.[11] Regional anesthesia with sedation may be preferable to general anesthesia for patients undergoing this form of therapy.[6,7,12,13] Despite the technical advances associated with "dry" lithotripsy, the stress response may be difficult to determine in individual patients. Contrary to the manufacturer's claim, many patients do feel pain and discomfort. Therefore, some form of intravenous sedation and/or analgesia with or without regional anesthesia is required. At present, there are no clear-cut data that support the clinical superiority of one type of lithotripter over another.[12] Furthermore, the optimum anesthetic technique for dry ESWL has not yet been established.[2] Despite improved fragmentation (86%) for midureteric calculi in the prone position,[13] at present, no comparable studies have established improved efficacy for UPJ or upper calyceal stones in the prone position. The prone position minimizes the distance and the amount of tissue between the skin and the stones and purportedly reduces attenuation of the shock wave energy.[12] The focal zone is also away from important structures near the renal pelvis including lung, colon, and small intestine, where gas is not likely to interfere with visualization of the stones.[12]

Potential adverse effects of shock waves on target tissues include injury to skin, renal tissue, heart and especially lung.[6,7] Bromage et al., in examining the respiratory effects of water immersion lithotripsy, used IV midazolam sedation with epidural anesthesia to pharmacologically control diaphragmatic-related stone excursion.[11] Stone movement abruptly decreased by an average of 60% within 90 seconds of IV midazolam.[11] However, approximately 20% of the patients developed moderate hypoxia ($SaO_2 \leq 88\%$). The study pointed out the intrinsic hazards of water immersion in lightly sedated patients for ESWL under regional analgesia. It is noteworthy that even in the absence of water immersion and epidural anesthesia, our patient developed mild hypoxia (SaO_2, 92%) with mild IV sedation and analgesia. This likely suggests a combination of factors, i.e., IV supplementation causing alveolar hypoventilation and pulmonary ventilation-perfusion dysfunction accentuated by hemidiaphragmatic paresis in the prone position, contributing to hypoxia during ESWL.

At present, no definitive studies have proven that variations of the number of shock waves required for successful ESWL are related to stone movement.[10,14] Further complicating the issue is the measurement of diaphragmatic movement versus stone movement - the precise correlation between the two has not been determined.[14] One must be cautious in assimilating the physiological effects of "dry" with those of water immersion lithotripsy. The cardiovascular and respiratory effects of water immersion are well-defined[6,7,11,15] and largely avoided in "dry" lithotripsy. Proponents of "dry" ESWL[2] argue that it might be specifically indicated for those patients with ischemic heart or valvular disease, where coping with the hemodynamic effects of water immersion,[15] epidural blockade,[6,11,13] or open nephro-lithotomy[13] would prove hazardous.

As with any procedure that might influence outcome, its potential benefit and efficacy must be weighed against its potential risks and adverse effects. The benefits derived from securing a stable stone, i.e., enhanced fragmentation with a paralyzed hemidiaphragm, must be balanced against the potential risks and adverse effects of performing and maintaining a phrenic nerve block under MAC with sedation. An incidence of 28% to 80% of ipsilateral hemidiaphragmatic paresis is reported after supraclavicular brachial plexus block[16,17] and 100% after interscalene block.[18] Pneumothorax is a well-recognized complication of both supraclavicular and interscalene blocks, albeit rare using the Winnie perivascular technique.[3] The risk of pneumothorax should always be included when informed consent is obtained for this procedure. Precautions to minimize the risk of iatrogenic pneumothorax relate to scrupulous attention to detail of needle insertion.[3] Fluoroscopic guidance was invaluable throughout this case to continually assess diaphragmatic paresis and to rule out early and delayed pneumothorax. Acute respiratory failure attributed to diaphragmatic paresis has been reported in the literature.[19,20] Conversely, hemidiaphragmatic paresis can also occur without respiratory symptoms or compromise. In a review of hemidiaphragmatic paresis associated with interscalene brachial plexus block,[18] less than 40% of patients noted any changes in breathing. Moreover, these changes were reported as clinically insignificant. In patients for ESWL with preexisting pulmonary dysfunction, more marked changes in ventilation might be expected. Because of the recognized incidence of pneumothorax and hemidiaphragmatic paresis, this technique is relatively contraindicated in patients with respiratory and/or renal failure who require bilateral intact diaphragmatic function to compensate for changes in respiratory and/or acid-base status.

This case report shows that cervical plexus anesthesia can be used effectively and safely to control diaphragmatic-related stone excursion. However, in the absence of well-controlled studies, one should not deduce nor conclude that this form of regional anesthesia confers any enhanced benefit for ESWL over present conventional anesthetic techniques. This procedure may be a useful adjunct in refractory lithotripsy involving large stones at the UPJ or renal pelvis in freely mobile kidneys requiring controlled fragmentation.

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