

Running Head: The Effect of Ventilation Mode on Renal Mobility During RIRS

The Effect of Ventilation Mode in Anesthesia on Renal Mobility During Retrograde Intrarenal Surgery. Single-Blind Randomized Study.

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Key words: renal mobility, RIRS, mechanical ventilation, general anesthesia, nephrolithiasis, ureteroscopy

Abstract

Purpose

Renal mobility can present challenges for surgeons during stone fragmentation. The respiratory setup of the mechanical ventilator during RIRS might affect renal mobility. The aim of this study was to evaluate the effect of high ventilation (HV) and standard ventilation (SV) modes on renal mobility during RIRS.

Materials and Methods

Patients who underwent RIRS at a single center between November2020andNovember2021 were retrospectively included in the study. Renal mobility was measured under fluoroscopic view in HVandSV modes during retrograde pyelography. The surgeon, who was absolutely blind about mechanical ventilation modes, was asked to assess the renal movement grade. After the ventilation mode was changed, the surgeon reassessed renal mobility. The data and the surgeon's assessment were recorded and compared to each other.

Results

A total of 86 patients with a mean age of 48.6 ± 15.7 years were included in the study. There was a significant difference between the SV and HV modes in terms of renal mobility in fluoroscopic view (17.1 ± 6.1 mm and 13.6 ± 5.2 mm, respectively; $p=0.007$). According to the surgeon's assessments, the grade of renal mobility was found to be significantly higher in the SV group 2.8 ± 1.1 compared to the HV group 2.2 ± 0.8 ($p=0.001$). Renal movement increased significantly under fluoroscopic vision as the renal grading of the surgeon increased ($p=0.013$). This data demonstrated that the surgeon's assessment of renal mobility was significantly correlated with fluoroscopic kidney movement.

Conclusion

Kidney movement was decreased significantly in HV mode during RIRS according to both fluoroscopic findings and surgeon assessment. Most surgeries of mobile kidneys were performed in HV mode, due to the surgeon's preference.

Key words: renal mobility, RIRS, mechanical ventilation, general anesthesia, nephrolithiasis, ureteroscopy

Introduction

Retrograde intrarenal surgery (RIRS) has been widely accepted and has become one of the most promising surgeries for the treatment of kidney stone⁽¹⁾. Retrograde intrarenal surgery is usually performed under general anesthesia (GA), but it can also be performed under regional anesthesia (spinal or epidural). Surgeons generally prefer general anesthesia during the operation due to the surgical field stability and to avoid possible complications related to patient factors. General anesthesia also enables the surgeons to change respiration frequency and tidal volume to decrease renal mobility⁽¹⁾. Several patient and stone related factors have been evaluated to document their effect on the safety and efficacy of RIRS, but there are limited data about the effect of renal mobility on RIRS⁽²⁻⁴⁾.

The stone-free status of RIRS depends on multiple factors, including patient-related properties and stone-related properties. Some factors can affect stone-free status and complications; these include stone volume, stone density, preoperative urine culture status, presence of previous extracorporeal shock wave lithotripsy (ESL), number of stones, and the usage of a ureteral access sheath^(4,5). Although several variables related to patient and stone characteristics have been evaluated, there are limited data about the effect of renal mobility on the efficacy and safety of RIRS. Renal mobility during the surgery might be a significant factor that could affect RIRS success and safety. Excessive renal mobility is one of the main challenges for the RIRS procedure. During the stone dusting, surgeons prefer to have an immobile stone to maximize their ability to eliminate the target. Any manipulations that

decrease the mobility of the stone might increase the success rate of the RIRS. Many techniques have been described to reduce renal mobility, such as abdominal belt application, periodic apnea technique, and high-frequency jet ventilation, but none of them has gained acceptance. Abdominal belt application, the oldest method, was used in the past during ESL to reduce renal mobility, but it has not gained acceptance due to insufficient efficiency^(6,7). The periodic apnea technique, which was described by Emiliani, was a promising method; however, the possibility of metabolic complications(hypercapnia) was a major disadvantage for this technique⁽⁸⁾. High-frequency jet ventilation (HFJV) may also be used during the RIRS procedure, but this technique does not allow for the use of inhalation-type anesthetics, and the end-tidal carbon dioxide and exhaled air volume cannot be monitored by the anesthetist⁽⁹⁾. For these reasons, any type of ventilation technique that will decrease the renal mobility during RIRS may have a significant advantage for the surgeon.

In this study, we aimed to compare the effects of standard ventilation (SV) mode with high ventilation (HV) mode on renal mobility during RIRS. The study's primary aim was to evaluate ventilation modes' effect on renal mobility during RIRS. The secondary aim was to confirm the relationship between renal mobility under a fluoroscopic view and the surgeon's assessment of renal mobility during the surgical procedure.

Materials and Methods

After the approval of the local ethical committee (No:2020.214.09.01), the patients who underwent RIRS by the same surgeon for the treatment of kidney stone at a single center between November 2020 and November 2021 were retrospectively included in the study. Sample size of our study was calculated as 80 participants according to G power analysis software (version 3.1.9.7). (effect size 0.5, alfa error 0.05, power 0.80). Randomization of participants was performed by using randomization software on the website. (<https://www.randomizer.org>) written informed consent was given to all patients before the

surgery. Patients younger than 18 years old; patients with a renal anomaly, a solitary kidney, a bleeding disorder, proximal ureteral stone, or multiple stones; and patients who had undergone previous ipsilateral percutaneous nephrolithotomy and/or open renal surgery were excluded from the study. In order to standardize the study population, patients who were treated without the insertion of an access sheath and surgeries that were performed with regional anesthesia were also excluded from the study. A standard protocol of general anesthesia was given to all patients by the same anesthesiologist to prevent possible bias. The preoperative evaluation was performed with history taking; physical examination; laboratory analyses, including urinalysis, urine culture, and serum creatinine level; and radiological evaluation with non-contrast computerized tomography (NCCT). Patients with a positive urine culture were treated with antibiotics according to the antibiogram, and surgeries were performed under sterile urine. The demographic and clinical characteristics of the patients, including age, gender, body mass index, urine culture status, presence of hydronephrosis, stone volume, stone density, surgical side, and the presence of preoperative double J stent, were noted. The stone volume was measured using the three-dimensional formula described by Sorokin et al. ⁽¹⁰⁾. Surgical technique was defined in our previous study ⁽⁵⁾. We used the same size laser probe (272 nm) for the stone dusting procedure was performed under 0.8 joule and 10 frequencies by holmium laser (Quanta system 2015, Italy), and stone fragments were broken into small pieces by using the popcorn mode of the laser. (1 joule, 15 frequency). Patients with residual stone fragment <4 mm was defined as stone free.

Anesthesia Protocol

The patients received 2 mg midazolam IM (intramuscular) as a premedication and were monitored with three-channel electrocardiography, noninvasive blood pressure, peripheral oxygen saturation, and bispectral index (BIS) in the operating room. The anesthesia was introduced intravenously with 2–3 mg/kg of propofol, 1 mcg/kg of fentanyl, and 0.6 mg/kg of

rocuronium. After ensuring adequate muscle relaxation, orotracheal intubation was carried out by an experienced anesthesiologist. Anesthesia was maintained with 1–2% sevoflurane in 4 L of 40%:60% O₂ and air mixture. Remifentanyl infusion was used at 0.1–2 mcg/kg/min after intubation during the surgery. The concentrations of sevoflurane and remifentanyl were set to a target BIS level between 40 and 60. Intravenous rocuronium was administered in a dose of 0.1 mg/kg to maintain adequate muscle relaxation.

A Dräger Primus (Germany) device was used for mechanical ventilation. The tidal volume and frequency were determined by the machine according to patient's age and weight with end-tidal CO₂ levels of 30–35 mmHg. SV mode was defined as 8–10 mL/kg tidal volume and 10–15 respirations/min. During HV mode, the tidal volume was decreased to 6–8 mL/kg and the frequency was increased to 15–18 respirations/min. No changes were made in the inspiratory expiratory ratio (1:2), FiO₂, and positive end-expiratory pressure (PEEP) parameters. All surgeries were started with SV mode without the knowledge of the surgeon. The surgeon was asked to grade the renal mobility, and the mode was changed to HV mode after grading. The surgeon was then asked to grade the renal mobility under HV mode. Then the surgeon decided to perform the surgery under the ventilation mode that he found more comfortable.

The surgery was started with cystoscopy and retrograde pyelography. During the retrograde pyelography, the researcher marked the tip of the lower calyx on the fluoroscopy screen (Siemens Siremobil Compact L, Germany) during the maximum inspiration and expiration phases of the SV and HV modes. The distances of the tip of the lower calyx on the fluoroscopy screen at respiration phases at both ventilation modes were measured. A demonstration of kidney movement is shown in Figure 1. In order to decrease the radiation exposure of the patients, the fluoroscopy was used during one inhalation and one exhalation period. Then, the surgeon was invited to the operating theater to proceed with the surgery. The surgeon was totally blind of the ventilation modes. During the stone fragmentation, the

researcher asked the surgeon to classify the renal mobility according to the classification described by Gadzhiev et al. ⁽¹¹⁾. Renal mobility classifications were described as follows: grade 1, very mobile kidney (extremely poor conditions for dusting); grade 2, significantly mobile (unsatisfactory conditions for dusting); grade 3, slightly mobile (satisfactory conditions for dusting); grade 4, almost immobile (good conditions for dusting); and grade 5, completely immobile (excellent conditions for dusting). This classification system was used in reverse to prevent confusion in our study. So, we defined that grade 1 renal mobility was identified as a completely immobile kidney, whereas grade 5 renal mobility was a very mobile kidney. As the surgeon defined the degree of renal mobility, the ventilation mode was changed and the surgeon was asked again to assess the renal mobility. The surgeon decided to continue the surgery on the ventilation mode that he found more comfortable.

Statistical Procedure

All data were evaluated using SPSS Statistics, Version 25 (IBM; Armonk, NY, USA) software. The distribution of data was evaluated by the Kolmogorov-Smirnov test. A chi-square test was performed for nominal variables in the groups. An independent t-test and one-way ANCOVA were used to analyze the parametric data. Mann-Whitney U, chi-square, Fisher's exact chi-square, and Kruskal-Wallis tests were used for the analysis of nonparametric data.

Results

A total of 86 patients with a mean age of 48.6 ± 15.9 were enrolled in the study. There were 50(58.1%) female and 36(41.9%) male patients. The mean operation time and the stone-free rate of the study population were 73.3 ± 28.4 min and 70.9%, respectively. Postoperative complications were observed in 11(12.8%) patients. The most frequent complications were hematuria, fever, and flank discomfort, which were classified as Clavien grade 1–2 complications. We observed that there was no ventilation mode–related complications during surgery in our study. The demographic and stone-related properties of the patients and

complications of the surgeries are given in Table 1.

In order to evaluate the accordance between the surgeon's assessment and renal mobility, we compared the surgeon's renal mobility evaluation with the fluoroscopic measurements. The mean fluoroscopy time during renal movement was 3.14 ± 0.36 sec. The mean distance of lower pole localizations in fluoroscopic images was 14.5 ± 5.3 mm in patients that the surgeon reported as grade 1 renal mobility during SV mode. The distance increased to 25.1 ± 1.4 mm in patients whom the surgeon reported the renal mobility as grade 5 ($p < 0.001$). Similar findings were also observed during HV mode. The renal mobility of all patients was also calculated under fluoroscopic view, and there was a significant difference between the SV and HV modes during the surgery (17.1 ± 6.1 mm and 13.7 ± 5.8 mm, respectively; $t(3,01)=76.1$, $p=0.007$). The distance of lower pole localizations increased significantly as the renal grading of the surgeon increased ($p=0.013$). This data demonstrated that the surgeon's assessment of renal mobility was significantly correlated with the fluoroscopic movement of the renal unit (Table 2). According to the surgeon's assessment, the grade of renal mobility was found to be significantly higher in the SV group (2.8 ± 1.1) compared to the HV group (2.3 ± 0.9 , $t(-14.7)=83.5$ $p=0.001$).

The renal mobility degree was reported as grade 3 and higher in 5 (59.3%) patients during SV mode. As the mode changed to HV mode, the surgeon reported a renal mobility regression in 44(82.3%) patients and preferred to continue in this mode. However, when the surgeon graded the renal mobility as grade 1 and 2 in 35(40.7%) patients, he preferred to continue in HV mode with only 8(22.9%) of these patients ($p < 0.001$). As a result, a total of 52 (60.5%) surgeries were performed under HV mode and 34 (39.5%) surgeries were performed under SV mode. When we compared the ventilation modes, demographic properties, and stone-related properties, we found similar intraoperative surgical variables, operation time, stone-free rates, and postoperative complications between the groups (Table 3).

Discussion

Usage of flexible ureteroscopy for the treatment of kidney stone has increased over the last two decades⁽¹²⁾. Renal mobility may be one of these challenges, and we believe that it is an underestimated subject. Previous studies have shown that renal mobility can affect the results of ESL, and less renal mobility can improve the success rates of ESL⁽¹³⁻¹⁵⁾. This may also be true for RIRS that targets stones in mobile kidneys by laser fiber, which is a challenging situation for surgeons. For this reason, any manipulation that decreases renal movement during RIRS may affect surgical success and surgery-related complications.

As a possible factor for renal mobility, we compared two different ventilation modes during RIRS. According to our knowledge, this is the first study comparing renal movement during SV and HV modes under fluoroscopic vision. The fluoroscopic findings showed that renal movement during SV mode was significantly higher than renal movement during HV mode (17.1 ± 6.1 mm and 13.7 ± 5.8 mm, respectively; $p=0.007$). The difference in renal movement during SV and HV mode was also noticed by the surgeon during RIRS. The surgeon preferred to continue the surgery under HV mode for nearly 80% of the patients with grade 3 and higher renal mobility. However, the same preference was observed for nearly 20% of patients with grade 1 and 2 renal mobility. Therefore, the alteration of ventilation mode from SV to HV during RIRS should be considered, especially in grade 3 and higher renal mobility.

There were two studies in the literature investigating the effect of ventilation mode on renal mobility during RIRS^(11,16). One of these studies was carried out by Gadzhiev et al. They found that renal mobility decreased significantly during small-volume but high-frequency jet ventilation mode⁽¹¹⁾. According to their results, the authors concluded that decreasing the tidal volume and increasing the respiration frequency during general anesthesia was an effective method to limit renal mobility during RIRS. We also observed similar findings that renal mobility decreased significantly during HV, when the tidal volume was decreased and the respiration frequency was increased. In Gadzhiev et al., the authors evaluated the renal mobility

according to the surgeon's assessment, which might be a subjective finding. One of the main differences in our study was the usage of fluoroscopic vision. Through fluoroscopic measurement, we were able to demonstrate the renal mobility more objectively and combine our findings with the surgeon's assessment.

Another study related to ventilation mode and renal mobility during RIRS was performed by Kourmpetis et al. The authors evaluated the effect of low ventilation (LV) mode (respiration frequency $\leq 8/\text{min}$ and tidal volume $< 500 \text{ ml}$) on RIRS and reported that it provided better conditions for stone fragmentation during RIRS. During this ventilation mode, the tidal volume and respiratory frequency were both decreased. As a result, the end-tidal CO_2 increased to 50 mmHg during LV mode, and the authors indicated that hypercapnia may lead to cardiovascular diseases, increased intracranial pressure, metabolic acidosis, and hyperkalemia^(16,17). However, we did not observe hypercapnia during HV mode. Decreasing the tidal volume with respiratory frequency increment did not adversely affect the physiological respiratory functions. The post-operative complication rates after the RIRS procedure varies between 7.9% and 20.5%. The post-operative complication rates of our study confirmed the literature with %12.8. We also observed that there was no ventilation mode-related complications during surgery in our study⁽¹⁸⁾.

All of the studies documented a decrease in renal mobility during RIRS by their special ventilation modes. The common property of these special ventilation modes was the decrease in tidal volume. This data showed that tidal volume is a significant parameter for renal mobility during RIRS. Decreasing the tidal volume without a change in respiratory frequency may lead to non-physiological results, like hypercapnia. We showed that HV mode was a safe and effective method to decrease renal mobility during RIRS.

Our study had some limitations. The first limitation was its retrospective nature. However, the data of the study was obtained during surgery, which might decrease the bias that

may possibly result from retrospective evaluation. The second limitation was the lack of patient randomization. All patients were started on SV and changed to HV mode. The surgeon was totally blind for the ventilation modes and assessed the surgery in a blind fashion. The study was designed to evaluate the effect of ventilation modes on the renal mobility during RIRS. For this reason, we were not able to evaluate the effect of ventilation modes on the efficacy and safety of RIRS. The other limitation of the study was the number of participants. We believe that prospective-randomized studies with a high number of participants are needed to understand better the effect of ventilation modes on renal mobility. Another limitation of the study was that this study could be performed with two or more blind surgeons. A study designed with an interpersonal assessment of renal mobility could gain more scientific power.

Conclusions

Renal mobility during RIRS decreased significantly during HV mode. Both fluoroscopic findings and the surgeon's assessment documented this finding. The decrease in renal mobility was more apparent in patients with highly mobile kidneys. Surgeons might consider changing the ventilation mode to HV when they feel uncomfortable during RIRS due to renal mobility.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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Accepted

Table-1 All of the patients' demographics

Number of patients	86
Age (year)	48.6±15.8

Gender		
	Male (%)	50(58.1)
	Female (%)	36(41.9)
BMI (kg/m ²)		27.5±4.9
Stone Location		
	Upper calyx (%)	10(11.6)
	Lower calyx (%)	29(33.8)
	Middle calyx (%)	11(11.8)
	Pelvis calyx (%)	36(41.8)
Surgical Side		
	Left (%)	42(48.8)
	Right (%)	44(51.2)
Stone size (mm ³)		472.1 (min 9.44- max 3563.2)
Stone density (HU)		1027.8±290.1
Operation time (min)		73.3±28.4
Postoperative complications (%)		11 (12.8%)
Clavien-Dindo classifications		
Grade 1	Hematuria (%)	4(36.3)
	Fever (%)	2(18.2)
Grade 2	Flank discomfort (%)	2(18.2)
Grade 3a	Stent migrations (%)	1(9.1)
Grade 3b	Pelvicalyceal extravasation (%)	1(9.1)
Grade 4a	Urosepsis (%)	1(9.1)
Grade 4b	Multiorgan dysfunction (%)	0
Grade 5	Death (%)	0
Stone free rate (%)		51(70.9)

* All decimals were rounded

Table-2 Comparison of degree of renal mobility with renal mobility under fluoroscopic view

Degree of renal mobility	1	2	3	4	5	p value
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Number of patients in standard ventilation mode (n)	12	23	22	27	2	
Fluoroscopic distance during standard ventilation mode (mm)	14.51±5.35	13.91±5.79	16.95±5.98	20.78±4.91	25.01±1.41	<0.001
Number of patients in high ventilation mode (n)	17	30	32	5	2	
Fluoroscopic distance during high ventilation mode (mm)	10.22±4.67	14.25±5.02	14.93±5.22	15.41±4.97	17.26±5.08	0.013

Table-3 Demographic and Clinical Properties in Standard and High Ventilation Mode

	Standard Ventilation (n:34)	High Ventilation (n:52)
Age (year)	51,8±17,1	46,5±14,6
BMI (kg/m ²)	26,70±4,52	28,04±5.06
Gender		
Male (%)	21(61.8)	29(55.8)
Female (%)	13 (38.2)	23(44.2)
Surgical side		
Left (%)	20(58.8)	22(42.3)
Right (%)	14(41.2)	30(57.7)
Stone location		
Upper calyx (%)	4(11.8)	6(11.5)
Lower calyx (%)	13(38.2)	16(30.8)
Middle calyx (%)	5(14.7)	6(11.5)

Pelvis calyx (%)	12(35.3)	24(46.2)
Stone size (mm ³)	726.8 (25.2-2658.6)	675.7(42.4-3245.7)
Stone density (HU)	1046,1±336.9	1015,7±257.6
Operation time (min)	75,88±33.51	71,63±24.44
Laser time (min)	50 (10-135)	45 (10-120)
Total laser pulse	11467(893-65063)	12550(2191-82465)
Stone-free status		
Yes (%)	22(64.7)	39(75.0)
No (%)	12(35.3)	13(25.0)
Postoperative complication		
Yes (%)	4(11.8)	7(13.5)
No (%)	30(88.2)	45(86.5)

Legends to Figures

Figure-1 The demonstration of measurement of renal mobility under fluoroscopic view.

a: Measurement of kidney movement in standard ventilation mode during expiration and inspiration by software (7.4mm). b: Measurement of kidney movement in high ventilation mode during expiration and inspiration by software (3.7mm). Firstly, resident marked the tip of lower calyx on the fluoroscopic images and drew a line through to vertebrae during the maximum inspiration and expiration phases of the standard and high ventilation modes. Then the difference between the inspiration and expiration lines was calculated by software.