

Article

Safety Profile of Suction-Assisted RIRS: A Prospective Analysis of Intraoperative Anesthetic Events

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Abstract

Background: Retrograde intrarenal surgery (RIRS) is a well-established minimally invasive technique for the management of renal stones. However, intraoperative physiological and anesthetic events during the procedure remain poorly characterized, particularly in the context of newer technologies such as suction-assisted systems. **Objective:** The objective of this study is to evaluate the occurrence of intraoperative anesthetic and physiological adverse events during suction-assisted RIRS and to assess its safety profile. **Methods:** We conducted a prospective, single-center observational sub-analysis of the “Trifecta factors in ureteroscopy” project. A consecutive cohort of 30 patients undergoing RIRS with suction ureteral access sheaths (sUAS) between August 2025 and January 2026 was analyzed. Baseline demographics, stone characteristics, and intraoperative anesthetic parameters—including airway pressure, Bispectral Index (BIS), and hemodynamic events—were prospectively recorded. Primary endpoints included intraoperative fever, sustained tachycardia, blood pressure alterations, and anesthetic complications. **Results:** The cohort had a mean age of 56.4 years with an equal gender distribution. Mean stone size was 12.9 mm, and mean operative time was 50.3 min. Intraoperative monitoring demonstrated stable anesthetic conditions, with a mean airway pressure of 16.3 cmH₂O and a mean BIS of 42.6. No major anesthetic complications or significant blood pressure fluctuations were observed. Minor intraoperative events included fever in 10% of cases and sustained tachycardia in 6.7%. No cases of intraoperative anesthetic instability were recorded. **Conclusions:** Within this descriptive cohort, suction-assisted RIRS under general anesthesia demonstrated a favorable safety profile with stable intraoperative parameters, though larger comparative studies are required to confirm these preliminary findings.



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1. Introduction

Retrograde intrarenal surgery (RIRS) has become a widely adopted minimally invasive approach for the management of renal lithiasis, particularly for stones ≤ 20 mm, due to its favorable safety profile and high efficacy. Continuous technological improvements in endoscopic equipment and laser systems have further enhanced procedural outcomes and expanded their clinical indications [1]. As a consequence, RIRS is increasingly performed

in patients with greater anesthetic complexity and in clinical scenarios that require a careful assessment not only of stone-free outcomes, but also of intraoperative physiological tolerance.

Despite its minimally invasive nature, RIRS involves several intraoperative physiological challenges that may impact patient safety. The procedure requires continuous irrigation, manipulation within the collecting system, and, in many cases, prolonged operative times. These factors can lead to fluctuations in intrarenal pressure, fluid absorption, and systemic responses that may translate into intraoperative anesthetic or hemodynamic events [2].

General anesthesia is traditionally preferred for RIRS, as it allows better control of ventilation and patient immobility, potentially facilitating surgical performance. However, both general and regional anesthesia have been shown to provide comparable surgical outcomes, and each technique carries specific physiological implications that may influence intraoperative stability [1,3,4]. Importantly, most available studies have focused on postoperative outcomes such as pain, complications, and stone-free rates, while intraoperative anesthetic events remain insufficiently explored.

Intraoperative complications during RIRS, particularly those related to anesthesia and physiological instability, are rarely reported in a standardized manner. Hemodynamic alterations, tachycardia, or intraoperative fever may reflect underlying mechanisms such as increased intrarenal pressure, systemic inflammatory response, or fluid absorption. However, these events are often underreported or not specifically analyzed as primary outcomes in the existing literature.

Current literature on suction-assisted RIRS has mainly emphasized stone-free rates, procedural efficiency, and postoperative infectious outcomes. Nevertheless, data focused on intraoperative anesthetic tolerance remain scarce. A clearer description of these events is important for reproducibility, for perioperative counseling, and for determining whether the use of suction-assisted systems introduces any detectable ventilatory or hemodynamic instability during the procedure.

Therefore, the aim of this prospective study was to evaluate the occurrence of intraoperative anesthetic and physiological adverse events during suction-assisted RIRS. By specifically focusing on intraoperative safety rather than traditional surgical outcomes, this study seeks to provide a more precise characterization of the anesthetic risk profile associated with this procedure.

2. Materials and Methods

This study was designed as a prospective, observational, single-center sub-analysis of the larger project titled “Trifecta factors in ureteroscopy”. The research protocol (Version 2, dated 14 July 2025) received formal approval from the Clinical Research Ethics Committee of the Hospital Universitario de Getafe on 22 July 2025 (Reference: CEIm 25/76). All procedures were conducted in strict accordance with the ethical standards of the institutional research committee and the Declaration of Helsinki. Prior to inclusion, all participants provided written informed consent.

2.1. Patient Selection and Cohort Characteristics

We analyzed a consecutive cohort of 30 patients who underwent retrograde intrarenal surgery (RIRS) using suction ureteral access sheaths (sUAS) at our institution between August 2025 and January 2026. Inclusion criteria encompassed adult patients (>18 years old) diagnosed with single or multiple renal stone burden indicated for elective RIRS in accordance with the European Association of Urology (EAU) guidelines, where the use of a suction ureteral access sheath (sUAS) was planned. Specifically, an 11/13 Fr ClearPetra sUAS (Well Lead Medical, Guangzhou, China) was utilized in all cases. Preoperative antibiotic prophylaxis was standardized across the cohort, consisting of a single intravenous

dose of Cefuroxime 1500 mg administered 30 min prior to surgical incision according to institutional guidelines. Exclusion criteria consisted of active untreated urinary tract infections, severe uncorrected coagulopathy, or structural anatomical abnormalities preventing the safe deployment of the access sheath. We recorded baseline demographics including

- Patient Profile: Age, gender, and Body Mass Index (BMI).
- Clinical Status: Comorbidities (Hypertension, Diabetes Mellitus, COPD, OSA, Ischemic Heart Disease), anticoagulation status, and American Society of Anesthesiologists (ASA) physical status.
- Anatomic/Surgical History: Presence of preoperative urinary diversion (e.g., double-J stent) and renal status (e.g., solitary kidney).

2.2. Anesthetic Protocol

All procedures were performed under general anesthesia following a standardized institutional protocol to minimize anesthetic variability. Premedication consisted of intravenous midazolam. Anesthesia induction was achieved using propofol, fentanyl, and rocuronium to facilitate endotracheal intubation. Anesthesia maintenance was managed via volatile anesthetics, titrated continuously to maintain a target Bispectral Index (BIS) between 40 and 60. Mechanical ventilation was executed in volume-controlled mode with a tidal volume, a positive end-expiratory pressure (PEEP), and a respiratory rate, adjusted to maintain normocapnia. Patient core temperature was monitored continuously throughout the entire intraoperative phase and immediate recovery utilizing a calibrated nasopharyngeal temperature probe.

2.3. Variable Definition and Data Collection

Prospectively collected variables were grouped into three domains. First, stone-related variables included maximum stone diameter, Hounsfield unit density, total number of stones, laterality, and number of affected calyces.

Second, intraoperative anesthetic monitoring variables included mean airway pressure, mean Bispectral Index (BIS), sustained tachycardia, and blood pressure alterations. These variables were selected to capture ventilatory stability, depth of anesthesia, and relevant hemodynamic changes during the procedure.

To ensure absolute clinical tracking precision, our primary endpoints were defined as follows:

- Intraoperative/Immediate Fever: A recorded core temperature $>38^{\circ}\text{C}$ occurring either during the surgical procedure or within the immediate Post-Anesthesia Care Unit (PACU) recovery phase (first 30 min post-extubation).
- Sustained Tachycardia: A documented heart rate exceeding 100 bpm lasting continuously for more than 5 consecutive minutes.
- Blood Pressure (BP) Alterations: A mean arterial pressure (MAP) deviation exceeding 30% from the pre-induction baseline value, or an absolute systolic blood pressure (SBP) <90 or >160 mmHg requiring immediate vasoactive or fluid intervention.
- Anesthetic Complications: The development of any major intraoperative respiratory or systemic adverse event, such as bronchospasm, laryngospasm, clinical aspiration, dental trauma, delayed emergence, or prolonged neuromuscular blockade.
- Surgical and Fluid-Dynamic Parameters: Irrigation was delivered via an automated irrigation pump calibrated to maintain a constant flow of 150 mL/min and pressure of 80 mmHG. Active, continuous suction through the ClearPetra (Well Lead Medical Co., Ltd, Guangzhou, China) 11/13 Fr sheath was regulated using a vacuum aspiration system from Hospital general supply up to pressure of -200 mgHg. Laser lithotripsy was performed utilizing a Holmium:YAG laser system equipped with

a 200 μm Moses technology laser fiber (Lumenis, Yokneam, Israel); pulse energy and frequency parameters were dynamically adjusted during the procedure according to stone characteristics (ranging from dusting to fragmentation settings).

The specific scope of this sub-analysis was strictly restricted to the intraoperative phase and the immediate post-anesthesia recovery timeline up to hospital discharge. No direct intrarenal pressure measurements were performed in this sub-analysis; therefore, physiological interpretation was based on the recorded anesthetic and clinical variables rather than direct pressure monitoring.

2.4. Statistical Analysis

Descriptive statistics were used to summarize the cohort. The normality of continuous variables was formally evaluated utilizing the Shapiro–Wilk test. Normally distributed data are presented as means with standard deviations (SD), while skewed data are expressed as medians with interquartile ranges (IQR) or full ranges. Categorical variables are presented as absolute frequencies and percentages. There were no missing data points across the primary intraoperative anesthetic and physiological datasets. To account for the exploratory nature and small sample size of this cohort ($n = 30$), 95% Confidence Intervals (95% CI) for the primary adverse event rates were calculated using the Clopper–Pearson exact method.

3. Results

3.1. Baseline Patient Characteristics

A total of 30 consecutive patients were included. Mean age was $56.4 (\pm 12.1)$ years and the cohort was evenly distributed by sex (15 men and 15 women). Mean BMI was $25.1 \pm 3.4 \text{ kg/m}^2$. Regarding anesthetic risk, most patients were classified as ASA II (40.0%) or ASA III (43.3%), whereas 16.7% were ASA I. Hypertension was the most frequent comorbidity, present in 13 patients (43.3%), followed by diabetes mellitus and anticoagulation therapy, each observed in 7 patients (23.3%). Other comorbidities listed in our screening protocol, including Chronic Obstructive Pulmonary Disease (COPD), Obstructive Sleep Apnea (OSA), and Ischemic Heart Disease, showed a frequency of 0.0% (0/30) in this specific cohort. The post-procedural length of hospital stay was formally assessed. The mean hospital stay for the series was 1.0 ± 1.66 , with a median stay of 0.5 days (range 0.5–7.0 days). In total, 86.7% of the patients (26/30) were safely discharged within 12 h of surgery (0.5 days) under our institutional ultra-short-stay protocol. Detailed data is shown in Table 1.

Table 1. Baseline patient and perioperative characteristics.

Variable	Result (N = 30)
Mean Age (years)	56.4
Sex (M/F), n (%)	15 (50%)/15 (50%)
BMI, Mean (kg/m^2)	25.1 ± 3.4
Hospital Stay (Days), Mean $\pm$ SD (Median; Range)	1.0 ± 1.66 (0.5; 0.5–7.0)
<i>ASA Physical Status, n (%)</i>	
-ASA I	5 (16.7%)
-ASA II	12 (40.0%)
-ASA III	13 (43.3%)
<i>Comorbidities, n (%)</i>	
-Hypertension (HTA)	13 (43.3%)
-Diabetes Mellitus	7 (23.3%)
-Anticoagulation therapy	7 (23.3%)

3.2. Lithiasis and Procedural Data

Stone burden was moderate overall. Mean maximum stone diameter was 12.9 mm (range 3–40 mm), and the mean number of stones per patient was 1.8; single-stone disease was present in 60% of procedures. Preoperative urinary drainage with a double-J stent was present in 36.7% of cases. Mean operative time was 50.3 min (range 10–108 min), supporting a relatively efficient procedure despite the use of a suction-assisted system.

3.3. Intraoperative Complications and Safety Profile

The main objective of the study was to describe intraoperative anesthetic and physiological safety during suction-assisted RIRS. In this cohort, intraoperative monitoring showed overall stable ventilatory and anesthetic conditions. Mean airway pressure was 16.3 cmH₂O, with no relevant pressure peaks documented during the procedures, and mean BIS was 42.6 (range 35–50), indicating an adequate and homogeneous depth of anesthesia.

No major anesthetic complications were recorded, and no significant blood pressure alterations were observed. Minor intraoperative adverse events were limited. Intraoperative or immediate PACU fever occurred in three patients (10.0%), while sustained tachycardia was documented in two patients (6.7%). No additional episodes of anesthetic instability requiring interruption of the procedure or major corrective measures were identified in the recorded cohort.

No major anesthetic complications or significant blood pressure (BP) fluctuations were reported (0%). Minor incidences are listed in Table 2:

Table 2. Summary of minor events with 95% confidence intervals.

Intraoperative Event	Frequency (n)	Percentage (%)	95% Confidence Interval (CI)
Intraoperative Fever	3	10.0%	2.1–25.6%
Sustained Tachycardia	2	6.7%	0.8–22.1%
BP Alterations	0	0.0%	0–11.6%
Anesthetic Complications	0	0.0%	0–11.6%

4. Discussion

The primary objective of this prospective study was to evaluate the safety profile and intraoperative complications associated with suction ureteral access sheaths sUAS during RIRS. Our findings demonstrate a favorable safety profile within this descriptive cohort, showing high hemodynamic and ventilatory stability, with a complication rate that aligns well with the standard benchmarks reported in current endourological literature.

A critical driver for this investigation was the physiological concern regarding the impact of active suction on the renal environment and its potential systemic repercussions. The localized vacuum effect created by suction-evacuation sheaths induces rapid shifts in intrarenal pressure and fluid dynamics. Theoretically, these sudden “mechanical-fluid” changes in the kidney could trigger autonomic reflexes, affecting heart rate or blood pressure, or even impact ventilatory mechanics through diaphragmatic irritation or systemic fluid absorption. This study was designed to monitor real-time anesthetic parameters to determine if these renal changes translate into systemic instability. Our results, showing no significant blood pressure fluctuations and stable mean airway pressures, suggest that the suction mechanism is clinically well-tolerated, although direct intrarenal pressure monitoring is required to definitively characterize the internal fluid-dynamic profile.

The clinical management of intrarenal pressure (IRP) remains an absolute cornerstone of safety during upper urinary tract endourology. Multiple experimental and clinical

models have demonstrated that standard gravity-fed or pressurized manual syringe irrigation can easily generate dangerous intrarenal pressure spikes frequently exceeding 100–300 mmHg. When IRP breaks past the critical physiological threshold of 30–40 mmHg, pyelovenous, pyelolymphatic, and pyelotubular backflow occurs. This mechanical breakdown acts as a direct conduit for the systemic translocation of bacteria, pelvic endotoxins, and inflammatory mediators into the bloodstream, rapidly triggering systemic inflammatory response syndrome (SIRS), severe urosepsis, or immediate endotoxemia. By utilizing active suction access sheaths, the endourologist aims to continuously decompress the pyelocaliceal system, balancing the continuous fluid inflow. As emphasized by Cai et al., the strategic choice of access technique and sheath diameter is a vital determinant of surgical success and long-term ureteral preservation [5]. Our descriptive data are aligned with the hypothesis that continuous active suction may counteract forced irrigation volume, potentially helping to avoid sustained high operating pressures. While direct intrarenal pressure was not measured in this sub-analysis, this decompressive mechanism could theoretically reduce the risk of macro-bacterial translocation, which might contribute to explaining why no cases of intraoperative septic shock occurred.

The contemporary medical literature has engaged in an active, long-standing debate regarding the clinical choice between general anesthesia (GA) and regional or neuraxial anesthesia (RA) for patients undergoing retrograde intrarenal stone disintegration. In an updated systematic review and meta-analysis conducted by Duan, Chen, and Sun, the authors compiled data evaluating RIRS outcomes under neuraxial blockade versus general anesthesia [1]. They concluded that while both approaches exhibit acceptable safety margins, general anesthesia is traditionally preferred by surgical teams due to its superior, absolute control over respiratory movements and tidal volume titration [1]. This factor becomes critically relevant when managing modern suction-assisted sheaths. The continuous mechanical clearance of microscopic “stone dust” requires a highly static and predictable endoscopic field. Uncontrolled diaphragmatic excursions or deep spontaneous breathing patterns seen in awake or sedated patients under regional anesthesia can cause the target kidney to oscillate continuously relative to the laser fiber tip, reducing fragmentation efficiency and increasing the risk of accidental laser-induced ureteral mucosa injury. As Sahan et al. observed in a prospective randomized trial, reported surgeon comfort and procedural ergonomics are significantly higher under general anesthesia because it completely eliminates these erratic respiratory movements [6]. Within our cohort, maintaining a deeply controlled plane of general anesthesia tracking a mean Bispectral Index (BIS) of 42.6 ± 3.1 provided the necessary conditions to maximize the technical efficiency of fragment evacuation without any technical hindrance or mucosal trauma.

Regarding safety, our observed rates of intraoperative fever (10%) and tachycardia (6.7%) are consistent with large-scale observational studies. Yoldas et al., in a series of over 500 patients, found that anesthetic technique (spinal vs. general) did not significantly alter the complication profile, suggesting that the endourological technique itself is the primary variable [7]. By adding suction to the equation, we observed a safety margin that aligns with these findings. Furthermore, Kwon et al. emphasized that while anesthesia does not significantly impact long-term renal function, minimizing operative time and pressure is vital for parenchymal protection [3]. The sUAS contributes to these goals by optimizing visibility and fragment clearance.

Procedural efficiency is another critical metric. Oztekin et al. noted that while regional anesthesia might offer advantages in specific access times, GA remains the gold standard for maneuverability [2]. Our mean operative time of 50.3 min is highly competitive, especially considering the additional steps required to manage the suction system. This efficiency

likely stems from the improved visibility provided by the active evacuation of “stone dust,” a benefit also noted in large series focusing on technique refinement [8].

The trend toward “fast-track” surgery is also reflected in our results, with a mean hospital stay of 1.0 ± 1.66 days (median 0.5 days). This matches the findings of Zeng et al., who demonstrated that optimized anesthetic and surgical protocols allow for high rates of discharge within 24 h [4]. The reduction in the need for repetitive basket extraction maneuvers when using suction sheaths likely decreases ureteral trauma, facilitating a smoother recovery. Finally, as Cakici et al. discussed, although GA may involve a slightly more complex immediate recovery than regional techniques, it provides the most controlled environment for complex intrarenal maneuvers [9].

To broaden our clinical interpretation beyond a single-arm descriptive framework, we must carefully analyze our findings against recent large-scale cohorts, propensity-matched trials, and systematic reviews exploring the interplay between anesthesia choice and endourological technique. A landmark prospective, observational trial published by Olivero et al. (2021) utilized a robust propensity score matching analysis to directly compare spinal anesthesia (SA) against general anesthesia during elective RIRS [10]. After balancing for multiple confounding variables, their matched cohort of 40 SA and 40 GA patients demonstrated equivalent 30-day stone-free rates (70.0% in the SA group versus 67.5% in the GA group, $p = 0.81$) and comparable secondary auxiliary procedure requirements within 90 days (22.5% vs. 25.0%, $p = 0.79$) [10]. Crucially, Olivero et al. reported a higher incidence of interrupted or aborted procedures in their spinal anesthesia arm (10.0% vs. 2.5%, $p = 0.166$) due to severe difficulties in safely navigating the flexible scope into specific calices under the influence of active, spontaneous breathing movements [10]. This specific finding highlights a fundamental benefit of our general anesthesia protocol: by combining active automated sUAS decompression with the absolute patient immobility and muscle relaxation of GA, we achieved a complete procedure in all cases, confirming that complete ventilatory control facilitates optimal sheath maneuverability and reliable pyelocaliceal access.

This operational paradigm is further complemented by the findings of Bosio et al. (2018), who published a large consecutive series assessing retrograde intrarenal surgery performed under spinal anesthesia within a fast-track setting [11]. Comparing 139 spinal procedures against 47 general anesthesia cases, they confirmed that RIRS under SA is highly feasible and effective, showing no significant differences in operating duration or overall complication rates when managed by an expert operator [11]. To validate this on a broader epidemiological scale, Baran et al. (2019) executed a massive multi-center retrospective analysis incorporating a total cohort of 1361 adult patients (709 undergoing SA and 652 undergoing GA) [12]. Their global analysis revealed identical stone-free success rates between the spinal (85.3%) and general anesthesia (83.5%, $p = 0.364$) cohorts, demonstrating that success is an independent factor relative to the surgeon when adequate case volumes are maintained [12]. Interestingly, Baran et al. reported a statistically shorter measured operation time in their spinal group (44.2 ± 14.2 min vs. 49.7 ± 19.1 min, $p = 0.014$), which they attributed to the omission of intubation and extubation lag times within the operating theater log [12]. Our reported mean operative duration of 50.3 ± 22.4 min is highly competitive with these massive databases, especially considering that managing a suction-assisted system requires additional technical steps to calibrate, assemble, and modulate the active vacuum tubing lines. The high efficiency noted in our series stems from the continuous vacuum evacuation, which maintains an unclouded visual field by clearing stone dust instantly.

To disassemble and synthesize these conflicting data on surgical efficiency, we must examine the recent meta-analysis published by Patil, Patel, and Pande (2024), which sys-

tematically pooled data from 12 comparative studies encompassing 2903 total patients [13]. Their meta-analytic architecture detected that central neuraxial blockade significantly reduced total operative room time (mean difference: -2.28 min, 95% CI: -3.51 to -1.04 , $p = 0.003$) compared to general anesthesia, but found no statistical variance regarding ultimate stone clearance rates, 24 h postoperative pain scores, or total length of hospital stay [13]. This lack of clinical difference in primary endpoints is mirrored in the comprehensive systematic review by Zhenkai Luo et al. (2020), which pooled six high-quality randomized controlled trials (RCTs) involving 580 patients [14]. Luo et al. confirmed that regional anesthesia achieved a mathematically similar stone-free rate compared to general anesthesia (Risk Ratio: 0.96, 95% CI: 0.91–1.02, $p = 0.22$) and was associated with a statistically lower early postoperative pain score (mean difference: -0.86 , $p = 0.0001$) due to the residual dermatomal sensory nerve block [15]. However, they found no evidence to suggest a significant difference in the occurrence of overall postoperative complications or hospital stays between the two groups [14].

Crucially, an extensive systematic review and meta-analysis by Ho et al. (2025), which pooled nine trials encompassing 2111 individuals, highlighted a vital sub-clinical physiological insight [16]. Their pooled data revealed that while effectiveness (SFR) and total complication rates were identical between RA and GA, general anesthesia maintenance could exert a potential negative effect on short-term renal function at the specific operative site [15]. This parenchymal stress is likely mediated by temporary renal blood flow reductions caused by positive-pressure ventilation and the systemic clearance of volatile anesthetics, muscle relaxants, and high-dose opioids [15]. Ho et al. noted that regional anesthesia preserves baseline renal perfusion more efficiently, and recommended that combining spinal anesthesia with mild conscious sedation offers the highest level of operator maneuverability and patient satisfaction [16]. While our prospective protocol relied on volatile general anesthesia, the continuous use of the active suction sUAS likely acted as a protective counter-mechanism: by maintaining a low-pressure environment, it eliminated pyelovenous fluid absorption and systemic bacterial translocation, protecting the renal parenchyma from combined mechanical and chemical stress. This protective synergy could explain why no major systemic cardiorespiratory events were triggered in our high-comorbidity patients.

Another critical factor when analyzing general anesthesia versus regional techniques is the overall institutional economic burden and specific post-anesthesia complication profiles [15,16]. The financial cost of general anesthesia maintenance is significantly higher than that of regional blocks due to the expensive pharmacology of volatile gases, advanced airway devices, and prolonged recovery monitoring requirements [15,16]. Sadi et al. reported an average anesthesia cost of 18.5 USD for general anesthesia compared to only 4.2 USD for spinal blocks ($p < 0.001$) [15]. Furthermore, spinal anesthesia carries a well-known risk of post-dural puncture headache (PDPH) [12]. In the large series by Baran et al. (2019), up to 6.4% of patients—particularly younger individuals—experienced prolonged hospitalizations exclusively due to severe post-spinal headaches [12]. In our series, by selecting general anesthesia, we completely eliminated the risk of PDPH. Although the global cost of GA is higher, our protocol offsets this liability by facilitating an exceptionally rapid post-procedural recovery. Our recorded mean hospital stay was 1.0 ± 1.66 days with a median of 0.5 days, allowing 86.7% of our patients to be safely discharged home on the same day of surgery under an ultra-short stay day-case model [16]. This fast-track success matches the findings of Zeng et al., who demonstrated that optimized preoperative care allows for high rates of discharge within 24 h, thereby maximizing hospital bed turnover and reducing the overall socio-economic burden [4].

This study has several limitations that should be acknowledged. First, the small sample size ($n = 30$) and its single-center, observational design restrict the direct generalizability of our findings and limit statistical power to detect rare intraoperative anesthetic catastrophes. Second, the lack of an active comparator or parallel control group prevents direct comparative conclusions regarding whether suction-assisted sheaths optimize mechanical airway ventilation profiles over traditional access sheaths. Third, direct intrarenal pressure (IRP) manometry was not performed due to the invasive clinical risks associated with pyelocaliceal instrumentation; thus, fluid-dynamic safety conclusions remain strictly indirect based on surrogate airway pressures and systemic vital signs. Finally, as an observational sub-analysis focusing on intraoperative stability, long-term delayed functional complications or outcomes past hospital discharge were not captured. Future multi-center randomized controlled trials are required to fully define the absolute clinical positioning of active suction techniques.

5. Conclusions

In conclusion, this prospective analysis provides preliminary descriptive safety data showing that the use of suction-evacuation sheaths in RIRS under general anesthesia is associated with high ventilatory and hemodynamic stability. The localized fluid-dynamic changes potentially induced by suction did not translate into detectable anesthetic instability or significant adverse events within our small cohort. While further multi-center comparative trials are mandatory to establish definitive clinical superiority, our initial findings indicate a highly favorable intraoperative safety profile for this technology.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

RIRS	Retrograde Intrarenal Surgery
sUAS	Suction Ureteral Access Sheath
GA	General Anesthesia
RA	Regional Anesthesia
BIS	Bispectral Index
BMI	Body Mass Index
ASA	American Society of Anesthesiologists

HU	Hounsfield Units
IRP	Intrarenal Pressure
BP	Blood Pressure
SIRS	Systemic Inflammatory Response Syndrome

References

1. Duan, M.; Chen, Y.; Sun, L. Outcomes of retrograde intrarenal surgery performed under neuraxial vs general anesthesia: An updated systematic review and meta-analysis. *Front. Surg.* **2022**, *9*, 853875. [\[CrossRef\]](#) [\[PubMed\]](#)
2. Oztekin, U.; Caniklioglu, M.; Selmi, V.; Kantekin, C.U.; Atac, F.; Gurel, A.; Sari, S. Do anesthesia methods in retrograde intrarenal surgery make difference regarding the success of ureteral access and surgical outcomes? *J. Laparoendosc. Adv. Surg. Tech.* **2020**, *30*, 273–278. [\[CrossRef\]](#)
3. Kwon, O.; Lee, J.-M.; Park, J.; Cho, M.C.; Son, H.; Jeong, H.; Ryang, S.H.; Cho, S.Y. Influence of anesthesia methods on surgical outcomes and renal function in retrograde intrarenal stone surgery: A prospective randomized controlled study. *BMC Anesthesiol.* **2019**, *19*, 239. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Zeng, G.; Zhao, Z.; Yang, F.; Zhong, W.; Wu, W.; Chen, W. Retrograde intrarenal surgery with combined spinal-epidural vs general anesthesia: A prospective randomized controlled trial. *J. Endourol.* **2015**, *29*, 401–405. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Cai, H.; Wu, X.; Chen, X.; Chen, W. Comparison of regional and general anesthesia for retrograde intrarenal surgery: A meta-analysis. *Ann. Med.* **2021**, *53*, 2110–2119. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Sahan, M.; Sarilar, O.; Akbulut, M.F.; Demir, E.; Savun, M.; Sen, O.; Ozgor, F. Flexible ureterorenoscopy and laser lithotripsy with regional anesthesia vs general anesthesia: A prospective randomized study. *Int. Braz. J. Urol.* **2020**, *46*, 1010–1018. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Yoldas, M.; Yoldas, T.K. Spinal versus general anesthesia in retrograde intrarenal surgery. *Arch. Ital. Urol. Androl.* **2022**, *94*, 195–199. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Bosio, A.; Alessandria, E.; Vitiello, F.; Vercelli, E.; Gontero, P. Flexible ureterorenoscopy under spinal anesthesia: Focus on technique, results, complications, and patients' satisfaction from a large series. *Urol. Int.* **2022**, *106*, 455–460. [\[PubMed\]](#)
9. Çakici, M.Ç.; Özok, H.U.; Erol, D.; Catalca, S.; Sari, S.; Özdemir, H.; Selmi, V.; Kartal, I.G.; Karakoyunlu, N. Comparison of general anesthesia and combined spinal-epidural anesthesia for retrograde intrarenal surgery. *Minerva Urol. Nefrol.* **2019**, *71*, 636–643. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Olivero, A.; Ball, L.; Fontaneto, C.; Mantica, G.; Bottino, P.; Pelosi, P.; Terrone, C. Spinal versus general anesthesia during retrograde intra-renal surgery: A propensity score matching analysis. *Curr. Urol.* **2021**, *15*, 106–110. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Bosio, A.; Dalmaso, E.; Alessandria, E.; Agosti, S.; Pizzuto, G.; Peretti, D.; Palazzetti, A.; Bisconti, A.; Destefanis, P.; Fop, F.; et al. Retrograde intra-renal surgery under spinal anesthesia: The first large series. *Ital. J. Urol. Nephrol.* **2018**, *70*, 333–339. [\[CrossRef\]](#)
12. Baran, O.; Aykac, A.; Sari, S.; Ates, A.; Ozok, U.; Sunay, M. Retrograde intrarenal surgery for stone disease under spinal anaesthesia, a minimally invasive technique. A retrospective analysis of 1467 cases. *Actas Urol. Esp.* **2019**, *43*, 248–253. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Patil, A.J.; Patel, A.R.; Pande, B.S. Retrograde intrarenal surgery with central neuraxial blockade versus general anesthesia: A systematic review and meta-analysis. *Saudi J. Anaesth.* **2024**, *18*, 231–239. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Luo, Z.; Jiao, B.; Zhao, H.; Huang, T.; Zhang, G. Comparison of retrograde intrarenal surgery under regional versus general anaesthesia: A systematic review and meta-analysis. *Int. J. Surg.* **2020**, *82*, 36–42. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Sadi, T.; Ekmekcioglu, O.; Ekmekcioglu, E.E.; Ayvaz, H.; Irkilata, L.; Avci, A. Effective and economical option of anesthesia in retrograde intrarenal surgery. *Ethiop. J. Health Sci.* **2023**, *33*, 1049–1054. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Ho, Y.; Wen, Y.-C.; Lee, L.-M.; Lin, K.-H.; Hsiao, C.-H.; Syu, S.-H.; Lai, B.C.-H.; Chung, C.-H.; Lin, Y.-W. Comparison of regional and general anesthesia for retrograde intrarenal surgery: A systematic review and meta-analysis. *Front. Surg.* **2025**, *12*, 1422660. [\[CrossRef\]](#) [\[PubMed\]](#)

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