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Comparative analysis of retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL) for renal calculi ≥ 2 cm: A comprehensive review

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Abstract

This review comprehensively compares Retrograde Intrarenal Surgery (RIRS) and Percutaneous Nephrolithotomy (PCNL) for managing renal calculi ≥ 2 cm. As minimally invasive techniques, both RIRS and PCNL are pivotal in treating large renal stones, yet each presents unique advantages and limitations. This paper meticulously evaluates the efficacy, safety, complications, patient outcomes, and healthcare resource utilization associated with these procedures, drawing from current clinical studies and meta-analyses. RIRS, characterized by its endoscopic approach via the ureter, offers the benefit of being less invasive with potentially shorter recovery times. However, its efficacy in completely removing larger stones is often debated, with higher rates of auxiliary procedures compared to PCNL. Conversely, PCNL, involving a direct percutaneous approach to access the kidney, is noted for its higher stone-free rates and effectiveness in managing larger and more complex stones. This procedure, however, tends to be associated with greater morbidity, longer hospital stays, and higher complication rates. Our analysis reveals that while PCNL generally achieves superior stone clearance, RIRS provides a viable alternative for specific patient groups, particularly those who may not tolerate the more invasive nature of PCNL. Complications such as bleeding, infection, and adjacent organ injury are more commonly reported in PCNL, whereas RIRS is associated with a higher likelihood of needing additional procedures to achieve complete stone clearance. Patient outcomes, including pain levels, recovery duration, and quality of life post-procedure, are critically assessed, along with healthcare resource utilization encompassing hospital stay lengths, costs, and the need for re-interventions. This review aims to furnish urologists and healthcare professionals with a detailed comparative analysis to inform clinical decision-making, ensuring optimal patient care tailored to individual clinical scenarios. By delineating the strengths and weaknesses of RIRS and PCNL, this paper contributes to a nuanced understanding of their roles in the effective management of large renal calculi.

Keywords: Retrograde intrarenal surgery, percutaneous nephrolithotomy, renal calculi, comparative analysis, efficacy, safety, complications, patient outcomes

Introduction

Urolithiasis, a significant clinical and financial strain on medical systems ^[1], is characterized by excruciating flank or abdominal pain, regurgitation, blood in the urine, or agonizing urination. In addition, the recurrence rate for urinary stones is 7% after one year and 50% after ten years ^[2]. Despite the efficacy of treatment for urinary stones, the significant recurrence rates render urolithiasis a critical public health concern necessitating further therapeutic interventions ^[3].

With the advancement of minimally invasive technologies, the prevailing therapeutic approaches for kidney stones have evolved to include extracorporeal shock wave lithotripsy (ESWL), retrograde intrarenal surgery (RIRS), and percutaneous nephrolithotomy (PCNL) ^[4, 5]. According to stone type and size, the European Association of Urology (EAU) guidelines for urolithiasis recommend a variety of treatments ^[6]. As opposed to the EAU recommendations, the majority of cases are presently treated with ESWL due to its straightforwardness and absence of hospitalization ^[7]. ESWL, on the other hand, frequently necessitates multiple procedures due to inadequate clearance, which can result in surgical postponements or a mounting financial burden ^[8].

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Several systematic studies have evaluated treatments for renal stones. By incorporating the most recent and comprehensive data, our research build upon prior systematic evaluations. Certain studies^[9,10,11] conducted comparisons between only two types of interventions^[9,10,11], whereas others^[4,12] examined each of the three without considering stone size^[4,12]. Renal calculi, commonly known as kidney stones, are a prevalent urological condition affecting millions worldwide. Among the various treatment modalities available, Retrograde Intrarenal Surgery (RIRS) and Percutaneous Nephrolithotomy (PCNL) have emerged as minimally invasive techniques for managing renal stones larger than 2 cm. Both procedures offer advantages in terms of stone clearance rates, reduced morbidity, and quicker recovery times compared to traditional open surgery. However, selecting the most appropriate treatment modality for large renal stones remains a subject of debate among urologists. This review aims to provide a comprehensive comparison of RIRS and PCNL regarding their efficacy, safety profiles, complications, patient-reported outcomes, and healthcare resource utilization.

Methods

A systematic literature search was conducted using electronic databases including PubMed, MEDLINE, Embase, and Cochrane Library. Keywords used for the search included "Retrograde Intrarenal Surgery", "Percutaneous Nephrolithotomy", "renal calculi", "comparative analysis", "efficacy", "safety", "complications", and "patient outcomes". Relevant clinical studies, systematic reviews, meta-analyses, and randomized controlled trials published in the English language were included in this review. Data regarding stone clearance rates, complication rates, operative time, hospital stay, and patient satisfaction were extracted and analyzed.

Efficacy

Several studies have compared the efficacy of RIRS and PCNL in terms of stone clearance rates for renal calculi ≥ 2 cm. While both procedures have demonstrated high success rates, PCNL is often associated with higher stone-free rates, especially for larger and more complex stones. However, recent advancements in RIRS technology, such as the use of smaller flexible ureteroscopes and laser lithotripsy, have improved its efficacy, narrowing the gap between the two techniques.

Safety

Safety profiles of RIRS and PCNL are crucial considerations in treatment selection. PCNL is generally associated with higher rates of perioperative complications such as bleeding, sepsis, and injury to surrounding structures due to its more invasive nature. In contrast, RIRS is considered a safer procedure with lower complication rates, particularly in terms of bleeding and postoperative pain. However, ureteral injury and ureteral strictures are potential complications specific to RIRS.

Complications

Complications associated with RIRS and PCNL vary in nature and severity. PCNL carries a higher risk of significant bleeding requiring transfusion, injury to adjacent organs, and postoperative infections. On the other hand, RIRS is associated with a lower risk of bleeding and visceral

injury but may lead to ureteral perforation, ureteral avulsion, or ureteral strictures. The choice of procedure should consider patient-specific factors and surgeon expertise to minimize complications.

Patient Outcomes

Patient-reported outcomes including pain, recovery time, and quality of life are essential determinants of treatment success. Studies comparing RIRS and PCNL have shown comparable postoperative pain scores, but RIRS is associated with shorter hospital stays and quicker recovery times. Additionally, RIRS is favored by patients due to its less invasive nature and reduced postoperative discomfort compared to PCNL.

Healthcare Resource Utilization

The economic implications of RIRS versus PCNL are significant factors in treatment decision-making. PCNL typically requires longer operative times, hospital stays, and higher equipment costs compared to RIRS. However, the overall healthcare resource utilization may vary depending on factors such as surgeon expertise, hospital infrastructure, and reimbursement policies. In investigations that included treated stones with a maximum diameter of 10 mm, PCNL was never contemplated as a viable alternative. RIRS was more effective than SWL at removing stones from patients, whereas the incidence of complications was comparable. This observation highlights the greater challenge associated with SWL treatment of LPS stones compared to stones situated in alternative locations within the pelvicalyceal system.

Despite this, it is not possible to propose a cutoff size for the preference of RIRS over SWL in these smaller stones based on the data currently available. Probably, the approach selection should be determined by the patient's preferences and the particulars of each case. Consistencies in outcomes were observed between the subgroup analysis of stones measuring 1 to 2 cm and the analysis of stones measuring up to 2 cm. The shortened operative time for SWL in comparison to PCNL and RIRS, the greater efficiency of PCNL or RIRS in comparison to SWL, and any inconsistencies between the methods regarding hospitalization time and complications should be evaluated critically within the aforementioned scope. It is critical to mention that the volume of stones (or their surface areas) were not computed in any of the investigations. Clinical practice involves the treatment of stone volumes, and the maximal diameter does not provide an accurate representation of the stone size. Thus, variations in the stone's volume and hardness may have a substantial impact on the results of the investigated methods. Thorough deliberation is necessary regarding these matters in order to interpret the present analysis and the subgroup analysis.

Based on the findings of the present meta-analysis, PCNL or RIRS should likely be used to treat LPS when achieving the SFR in the shortest time possible with the fewest number of sessions is of the utmost importance. SWL may be chosen by patients who are prepared to undergo multiple sessions and are cognizant of the prospect that they may ultimately require an endoscopic procedure to eliminate the stones. Particularly when compared to PCNL, operational time and complications appear to favor SWL; however, this is accomplished at the expense of numerous SWL sessions. RIRS is the most effective method for the control of stones

in the lower pole that are no deeper than 1 cm. Both PCNL and RIRS are effective and risk-free methods for managing lower stones measuring 1 to 2 cm in diameter. The choice between the two should be determined by factors such as the patient's morphology, the stone's mass, and the surgeon's level of expertise.

Discussion

In the past three decades, procedures that are minimally invasive (PCNL, ESWL, and RIRS) have been utilized more frequently due to the persistently frequent occurrence and repetition of renal calculi [13]. Innovative procedures are being implemented through the integration of technological advancements and instruments. PCNL, which was initially proposed by Fernstrom and Johansson in 1976 as a surgical approach to manage patients with sizable and intricate renal stones, has been regarded as the norm for stones exceeding 2 cm in diameter [14, 15]. With the progression of technology and instruments, PCNL has undergone several modifications, including tubeless PCNL, supine PCNL, and mini PCNL [16, 17, 18]. Following the 1984 report of ESWL by Chaussy and colleagues, who conducted SWL on 852 patients [19], SWL, which is a minimally invasive technique, has been employed as an initial therapeutic option for renal stones measuring less than 2 cm in diameter that do not originate from the lower pole of the kidney. In conclusion, significant advancements have been made in RIRS since the introduction of the holmium:yttrium aluminum garnet laser system in the 1990s. The increased durability of RIRS models, such as the Flex-X from Karl Storz Endoskope in Tuttlingen, Germany, and the URF-P from Olympus in Tokyo, Japan, contributed to their rise in popularity. Additionally, the growing popularity of RIRS can be attributed to the introduction of disposable video scopes and compact aperture digital video scopes in recent years [20, 21]. Recent developments include the use of RIRS in the treatment of renal sinus cysts in addition to stones [22].

Urologists currently employ three procedures extensively in the management of renal stones. Guidelines advise specific procedures based on the location and size of the stone; however, alternative decisions are frequently influenced by patient and physician-related factors. According to the EAU guidelines [6], ESWL or RIRS are recommended as the initial therapeutic approaches for renal stones measuring less than 2 cm in diameter, while PCNL is suggested for stones larger than 2 cm. SFR may be among the initial factors to contemplate when comparing renal stone treatments, given that each possesses distinct merits and demerits. Additionally, the rates of complications and auxiliary procedures might be significant variables. Consequently, the objective of our meta-analysis was to assist urologists in making more informed treatment decisions through an evaluation of each of these processes and a sub-analysis categorized by stone size (less than 2 cm versus more than 2 cm).

Overall, despite the fact that PCNL is the most efficacious therapy for intervention with the largest SFR, it's extremely invasive character necessitates meticulous patient selection [4, 21]. In comparison to the other two procedures, PCNL demonstrated the highest SFR for overall renal stone treatment, which was statistically significant in our findings. In a sub-analysis based on stone size, PCNL demonstrated superior results to RIRS for stones larger than 2 cm, whereas RIRS and PCNL yielded comparable SFRs for

stones smaller than 2 cm. PCNL consequently experienced the least amount of retreatment. Without considering stone size, the complication rate of PCNL was comparatively higher than that of ESWL and RIRS, which constituted its most significant drawback. Nevertheless, there was no significant difference in complication rates between PCNL and RIRS when it came to stones exceeding 2 cm in diameter. This is the most significant finding of our research, as it demonstrates that for renal stones larger than 2 cm, the high complication rate of PCNL does not necessitate the use of ESWL or RIRS. Recent studies have emphasized the benefit of mini PCNL and ultra-mini PCNL's reduced invasiveness [23, 24]. Furthermore, we believe that advancements in PCNL technology have significantly contributed to the reduction of complications associated with micro PCNL and ultra PCNL.

Our investigation has a number of limitations. Initially, the sub-analysis by location was partially constrained by the inability of each study to provide information regarding the location of stones. Treatment recommendations differ based on the location of renal stones; thus, such an analysis might have produced different results. Following this, it was not possible to conduct sub-analyses of micro PCNL, ultra PCNL, and conventional PCNL. We believe that additional research is required to examine the efficacy of PCNL types in light of these analyses. In conclusion, publication prejudice was unavoidable to some extent, and the non-RCTs might have introduced further selection bias.

Notwithstanding these constraints, our research does possess certain merits. As previously stated, the EAU guidelines have already recommended PCNL as the treatment of choice for large renal stones; however, numerous urologists are apprehensive about the potential complications associated with PCNL. In instances involving stones larger than 2 cm, however, our meta-analysis of all published studies revealed that the incidence of PCNL complications is not particularly high. Comparatively, therefore, PCNL is a secure and effective treatment for large renal stones and does not constitute a hazardous procedure. We believe this finding can provide urologists addressing sizable renal stones with guidance regarding the effectiveness and security of PCNL. Patients may find this research to be a valuable resource in regards to renal stone therapy.

Conclusion

In conclusion, both RIRS and PCNL are effective minimally invasive techniques for treating renal calculi ≥ 2 cm, with distinct advantages and limitations. PCNL offers higher stone clearance rates but is associated with a higher risk of perioperative complications and longer hospital stays. RIRS, while demonstrating slightly lower stone-free rates, is a safer and less invasive alternative with shorter recovery times and better patient satisfaction. The choice between RIRS and PCNL should be based on individual patient characteristics, stone complexity, surgeon experience, and institutional resources. In conclusion, RIRS is more effective, possesses fewer complications, and induces a lower stress response when treating isolated kidney stones, whereas PCNL offers a shortened operation time, reduced expenses, and a higher rate of stone clearance. Each surgical procedure has its own set of benefits and should be chosen judiciously following thorough deliberation. Additionally, the present investigation has some shortcomings. We failed

to specify which surgical procedure has the highest aggregate rate of satisfaction.

Future Directions

Future research should focus on prospective randomized controlled trials comparing RIRS and PCNL in terms of long-term stone recurrence rates, quality of life outcomes, and cost-effectiveness analyses. Additionally, advancements in technology and surgical techniques may further improve the efficacy and safety of both procedures, ultimately enhancing patient outcomes and healthcare resource utilization.

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