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NEPHROLOGY - REVIEW

Alternative renal biopsies: past and present

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Abstract Renal biopsy techniques have been used commonly worldwide for more than 70 years. They play an important role in the diagnosis, treatment, and prognosis of various renal diseases. Percutaneous renal biopsy (PRB) is currently the most important and widely used renal biopsy method. Although >90% of renal biopsies are PRBs, in certain settings, alternative renal biopsy techniques must be used, such as open, laparoscopic, transjugular, and transurethral renal biopsies. This review describes the history, advantages, and disadvantages of the various renal biopsy methods and discusses their current and future uses.

Keywords Renal biopsy · Open renal biopsy · Laparoscopic renal biopsy · Transjugular renal biopsy · Transurethral renal biopsy

Introduction

As a method to obtain human renal tissue, the establishment of the renal biopsy and its clinical application made an important contribution to the field of nephrology. Renal biopsies play an important role in the diagnosis, treatment, and prognosis of various renal diseases.

Renal biopsy techniques were introduced in the 1920s and have been used commonly worldwide ever since. Percutaneous renal biopsy (PRB) currently is the most important and widely used method of renal biopsy. Indeed, PRB is used in >90% of patients undergoing renal biopsies. However, in some special cases, open, laparoscopic, transjugular, and transurethral renal biopsies are necessary. The purpose of the review is to discuss the history, advantages, and disadvantages of the various renal biopsy methods, as well as their current and future uses. We hope this work will stimulate more interest and related clinical research in this area. If various types of renal biopsy techniques can be used widely, patients with kidney disease will gain more benefit from them.

History of renal biopsy

In 1923, Gwyn [1] performed the first reported open renal biopsy. The initial approach in open renal biopsy involved exposing the lower pole of the kidney under general anesthesia, and then cutting into the renal tissue with a scalpel and suturing for hemostasis. Since then, open renal biopsy has benefited from various improvements [2–8]. The first description of PRB was published by Iversen and Brun in 1951 [9, 10]. Using an aspiration liver biopsy needle and intravenous pyelography, they biopsied patients in the sitting position, reporting adequate tissue diagnosis in <40% of the biopsies. Kark and Muchrake [11, 12] later modified the procedure. First, they performed renal biopsies with the patient in a prone position, with a sandbag placed under the abdomen to limit mobility of the kidney. Second, instead of using an aspiration liver biopsy needle, they introduced the Franklin-modified Vim-Silverman needle. Finally, they used a lumbar puncture needle to localize and anesthetize the kidney before passing the biopsy needle. In 1954, they published their results, achieving adequate tissue diagnosis in 96% of biopsies and no major complications. Subsequently, PRB became the principal method of renal biopsy and has been used widely ever since.

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The positioning method for renal biopsy was blind or used intravenous pyelography before the 1980s. With newer technology, the use of real-time ultrasound (US) guidance [13] and automated biopsy needles has increased the diagnostic success rate to >95% [14–16]. Subsequently, computed tomography (CT)-guided localization has been applied in renal biopsy [17, 18]; this is particularly suitable for patients in whom the kidneys are otherwise difficult to image.

Transjugular renal biopsy was introduced by Mal et al. [19]. Influenced by intravenous liver biopsies, they improved the intravenous liver biopsy needle and then successfully performed transjugular renal biopsies [19, 20].

Laparoscopic renal biopsy, another method of procuring renal tissue when there is a contraindication to a percutaneous approach, was first reported by Squadrito and Coletta [21].

Later, a less invasive approach than laparoscopy, the transurethral renal biopsy, was introduced [22]. Transurethral renal biopsy can serve as an extension to cystoscopic examination and negates the need for percutaneous biopsy, which is more painful and invasive. Since then, there have been no reports on new renal biopsy methods according to a literature search.

PRB: the standard method of renal biopsy

Presently, PRB is the standard method of renal biopsy and is used widely. Puncture guidance by anatomical location (blind biopsy) [12] and intravenous pyelography [9, 10] have essentially been eliminated from practice. Currently, there are two major guidance methods: US and CT. Renal biopsy guided by US has the advantages of being a simple and rapid operation, with a high success rate and few complications. Disadvantages include the possibility that the operator could puncture a large vessel and the poor visualization due to body habitus. The most common post-biopsy complications are macroscopic and gross hematuria, perinephric hematomas, arteriovenous fistulas, and injuries to blood vessels and surrounding organs [11, 23–26].

The advantages and disadvantages of CT-guided renal biopsy are similar to those of US. The greatest advantage of CT guidance is that it can be used when US imaging of the kidney is difficult, such as in obese patients (body mass index >30 kg/m^2) [17, 18]. Although clinicians have made improvements to the two biopsy guidance methods [27–29], there is no significant difference in the success or complication rate between the two methods. However, because CT guidance cannot be visualized in real time, takes longer and costs more than US guidance, development of CT-guided renal biopsy has been limited.

Alternative renal biopsies

PRB is used widely and is currently the standard method of renal biopsy. Although >90% of renal biopsies are PRBs, some patients have contraindications to PRB; in these cases, other renal biopsy methods have been attempted. The various types of renal biopsy are described in the following section.

Open renal biopsy

An open renal biopsy is the most ‘primitive’ type of renal biopsy, characterized by the need for direct exposure of the lower pole of the kidney. The initial approach in open renal biopsy involved exposing the lower pole of the kidney under general anesthesia, and then cutting into the renal tissue with a scalpel and suturing for hemostasis; this was first reported in 1923 [1]. Since then, open renal biopsy has been subject to various improvements [2–8]; in addition to general anesthesia, local anesthesia has been used, as have negative-pressure puncture needles and biopsy forceps. The advantages conferred by these changes include a smaller incision and no requirement for sutures (for hemostasis) when electrocautery is used. The safety of open renal biopsy has also been improved.

A study on open renal biopsies was reported in 2010 by researchers at Vanderbilt University in the USA [30]. In the series of 115 patients, indications included morbid obesity, failed PRB, coagulopathy, and a solitary kidney. In total, 34.8% of the patients had a serum creatinine level >3.0 mg/dL and 17.4% were dialysis dependent. There were 43 complications in 36 patients. The mortality rate after surgery was 0.8%. There were major complications in seven (6.1%) patients, including cardiac arrest, stroke, sepsis, reoperation, and reintubation. There were minor complications in 31 (27%) patients, the most common being wound infection, pneumonia, intraoperative transfusion of >2 units, arrhythmia, postoperative retroperitoneal bleed, and deep vein thrombosis.

The advantages of open renal biopsy include that it is directly visible with the naked eye, tissue adequacy is 100% [8], multiple sites can be used to aid in the diagnosis of focal renal disease, and it can be used in patients for whom PRB failed or is difficult. Disadvantages of open renal biopsy are similar to those of any open surgery. Thus, there are certain risks related to anesthesia and surgery as well as postoperative complications and even mortality in a certain proportion of cases. Additionally, the included references show longer operation times and higher costs for open renal biopsies. Delayed recovery has

also prevented widespread adoption of open renal biopsy. Although open biopsy may still be performed when a renal biopsy is required in patients who are undergoing abdominal surgery, with the development of minimally invasive laparoscopic techniques, the disadvantages of open renal biopsy are more obvious and few physicians use this method anymore.

Laparoscopic renal biopsy

Laparoscopic renal biopsy is another method for procuring renal tissue when there is a contraindication to a percutaneous approach. In a sense, laparoscopic renal biopsy is still an 'open' renal biopsy. However, recently, laparoscopic surgical techniques have been used widely in many fields and have gradually come to be regarded as independent from traditional open surgery. The procedure requires general anesthesia and two laparoscopic ports for a retroperitoneal approach. Because of its advantages of limited trauma, a short operation time, and fast recovery, laparoscopic renal biopsy was readily adopted by clinicians.

The method was first described by Squadrito and Coletta [21], and it has been used by surgeons subsequently on many occasions. Indications for a laparoscopic renal biopsy include a failed percutaneous biopsy, morbid obesity, solitary kidney, chronic anticoagulation/coagulopathy, religious considerations (refusal of potential blood transfusion), and abnormal anatomy of the urinary system (multiple bilateral renal cysts and bilateral pelvic kidney) [31–36]. Previously, the operative duration of laparoscopic renal biopsy was 1.5–2 h and the mean estimated blood loss was 25–67 mL in the early stage [36, 37]. The main complications are hemorrhage and hematoma formation. However, with advances in technology, the mean operation duration has been reduced to 1 h and the mean estimated blood loss to 10 mL [38]. The incidence of surgical complications has also been reduced. Our own data are similar (unpublished). In a series of 42 patients using this technique, indications in addition to those mentioned previously included the differential diagnosis of acute or chronic renal injury (patients already on dialysis) and deaf-muteness (resulting in difficulties in cooperation between physicians and patients during the PRB procedure).

Thus, the advantages of laparoscopic renal biopsy are similar to those of open biopsy: Adequate tissue is obtained readily and can be drawn from multiple sites, which can contribute greatly to the diagnosis of kidney diseases. Furthermore, it is a minimally invasive surgery with a short operation time, few complications, and quick recovery and can be used for patients for whom PRB failed or there is a high risk of failure. Disadvantages of laparoscopic renal biopsy include the inherent risks associated with anesthesia and surgery, and postoperative complications in a certain proportion of cases. The operation costs are also higher than those for PRB. Laparoscopic renal biopsy is a safe alternative to percutaneous biopsy when uncorrectable contraindications are present.

Transjugular renal biopsy

The most important advantages of transjugular renal biopsy are simultaneous biopsy of different organs, for example the liver and kidney [39], and that it can be performed in patients with severe coagulopathies. Transjugular renal biopsy was first introduced by Mal [19, 20]. The procedure began with the insertion of a 9-F vascular sheath into the right internal jugular vein. The location of the catheter was confirmed by renal venography. A 15G needle was used to obtain tissue specimens. However, initial results were not satisfactory, with a success rate of only 76%. Failure was due to a small-sized kidney or anatomical anomalies of the right renal vein.

In 2000, Cluzelp compared the safety and effectiveness of transjugular renal biopsy with those of PRB for the diagnosis of renal parenchymal disease [40]. The transjugular route was chosen if there were bleeding disorders, abnormal clotting parameters accompanied by hepatic disease, uncontrolled hypertension, morbid obesity, or a solitary kidney, or if the patient was undergoing biopsies of multiple organs (heart and kidney, or liver and kidney), or if the PRB approach failed. The mean number of glomeruli obtained by PRB (95.5%) and transjugular renal biopsy (95.8%) was not statistically significantly different, and there was also no significant difference in the number of major complications (3 vs. 4). Transjugular renal biopsy was associated with three major complications (large perirenal hematomas), two of which were embolized successfully with microcoils without substantial loss of renal parenchyma; the third occurred in a patient in whom blood transfusion was required. In that case, an additional jugular venous puncture was associated with a major complication that necessitated a blood transfusion. Since then, improvements have been made in the method of transjugular renal biopsy and with respect to the surgical instruments used [41–45]. In 2013, a transjugular renal biopsy was performed successfully for a transplanted kidney via the ipsilateral femoral vein [46].

Transjugular renal biopsy is relatively safe. First, the needle is passed through the wall of the vein into the surrounding renal cortex and is directed away from the large vessels; any bleeding that occurs should be returned to the venous vessels and as such is self-limited bleeding. Once renal capsule perforation has occurred, accompanied by

obvious extravasation, selective embolization is usually performed later. Certainly, selective embolization is an arterial procedure, after the patient shows signs of ongoing bleeding. In clinical practice, transjugular renal biopsy has been shown to be relatively safe. Transjugular renal biopsy has diagnostic yield and safety similar to those of PRB and allows for multiorgan biopsies during the same procedure. It can be recommended in patients with PRB contraindications (especially those with severe coagulopathies) or in whom PRB failed. A disadvantage of transjugular renal biopsy is that its costs are higher than those of PRB. Furthermore, it requires the use of contrast, so experienced interventional radiologists are needed and there is a risk of contrast-induced nephropathy.

Transurethral renal biopsy

Transurethral renal biopsy can serve as an extension to cystoscopic examination. A needle sheathed in a catheter is advanced into the upper calix through the lumen of a transurethrally placed catheter and used to biopsy the renal cortex. The transurethral biopsy technique is less painful, less invasive, and simpler than the open and laparoscopic approaches. However, the technique is used primarily in patients who are undergoing a cystoscopic examination and do not wish to undergo PRB separately, or who undergo a renal biopsy with potential urinary system tumors. Transurethral biopsy is largely performed by ureteroscopy. Ureteral brush biopsies can be obtained at the time of a nephrostomy or nephroureteral stent placement [47]. Thus, this technique does not have wide clinical application and only a few case reports have been published to date [22, 48].

Conclusions

In summary, renal biopsies play an important role in clinical on kidney disease. Renal biopsy is an indispensable method of pathological examination for the renal specialist. PRB is used widely and is the standard renal biopsy method at present. However, in some special cases, open, laparoscopic, transjugular, and transurethral renal biopsies are necessary. With continual developments in science and technology, these alternative methods of renal biopsy can be further improved and refined. Thus, renal specialists have options in cases at high risk with a normal PRB, and patients with kidney disease should derive more benefit from various types of renal biopsy techniques.

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Compliance with ethical standards

Conflict of interest We have had no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated. The results presented in this paper have not been published previously in whole or part.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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