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A Literature Review of Renal Surgical Anatomy and Surgical Strategies for Partial Nephrectomy

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Abstract

Context: A detailed understanding of renal surgical anatomy is necessary to optimize preoperative planning and operative technique and provide a basis for improved outcomes.
Objective: To evaluate the literature regarding pertinent surgical anatomy of the kidney and related structures, nephrometry scoring systems, and current surgical strategies for partial nephrectomy (PN).
Evidence acquisition: A literature review was conducted.
Evidence synthesis: Surgical renal anatomy fundamentally impacts PN surgery. The renal artery divides into anterior and posterior divisions, from which approximately five segmental terminal arteries originate. The renal veins are not terminal. Variations in the vascular and lymphatic channels are common; thus, concurrent lymphadenectomy is not routinely indicated during PN for cT1 renal masses in the setting of clinically negative lymph nodes. Renal-protocol contrast-enhanced computed tomography or magnetic resonance imaging is used for standard imaging. Anatomy-based nephrometry scoring systems allow standardized academic reporting of tumor characteristics and predict PN outcomes (complications, remnant function, possibly histology). Anatomy-based novel surgical approaches may reduce ischemic time during PN; these include early unclamping, segmental clamping, tumor-specific clamping (zero ischemia), and unclamped PN. Cancer cure after PN relies on complete resection, which can be achieved by thin margins. Post-PN renal function is impacted by kidney quality, remnant quantity, and ischemia type and duration.
Conclusions: Surgical renal anatomy underpins imaging, nephrometry scoring systems, and vascular control techniques that reduce global renal ischemia and may impact post-PN function. A contemporary ideal PN excises the tumor with a thin negative margin, delicately secures the tumor bed to maximize vascularized remnant

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parenchyma, and minimizes global ischemia to the renal remnant with minimal complications.

Patient summary: In this report we review renal surgical anatomy. Renal mass imaging allows detailed delineation of the anatomy and vasculature and permits nephrometry scoring, and thus precise, patient-specific surgical planning. Novel off-clamp techniques have been developed that may lead to improved outcomes.

1. Introduction

The incidence of renal tumors has been increasing over the past several decades [1]. The majority of these tumors are diagnosed at clinical stage T1 [2] and are amenable to partial nephrectomy (PN), which is the accepted surgical treatment. More recently, minimally invasive PN has become a viable alternative to open PN (OPN) and is routinely performed at many centers worldwide [3]. Much effort has been made to integrate the anatomy of the renal mass and its vasculature into current concepts [4,5]. A detailed understanding of surgical anatomy is necessary to optimize preoperative planning and operative technique, thus providing a basis for maximizing oncologic and functional outcomes. The purpose of this article is to provide a contemporary overview of renal surgical anatomy and anatomy-based issues for PN surgery, such as imaging, nephrometry scoring systems, novel vascular control techniques that reduce global renal ischemia, and factors impacting post-PN function and oncologic outcomes.

2. Evidence acquisition

The Medline, Embase, and Web of Science databases were searched without time limit on August 1, 2014 using the terms "partial nephrectomy" OR "nephron-sparing surgery" in conjunction with "anatomy" (MeSH), "ischemia", "renal function", "margin", "adrenalectomy", "lymphadenectomy", OR "complications". Both free-text protocols and medical subject headings (MeSH) were used in Medline, while free-text protocols were run in Embase and Web of Science. Autoalerts in Medline were also run, and reference lists of original articles, review articles, and book chapters were searched for further eligible articles. The search was limited to the English literature. Articles that did not address the topics were excluded, and the full text of the remaining articles was reviewed. A list of articles that were judged to be highly relevant by the junior and senior authors was circulated among the coauthors, and a final consensus was reached on the structure of this review and the articles included. In addition, during writing of the manuscript, pertinent contemporary articles were identified in an attempt to include the most recent data.

3. Evidence synthesis

3.1. Surgical anatomy of the kidney

The right kidney is located approximately 1–2 cm lower than the left kidney because of the location of liver. The diaphragm covers the upper third of the kidneys posteriorly, where there is also a close relationship to the pleura that extends to the level of the 12th rib. Anteriorly, the right kidney is bordered by the liver and the right colonic flexure. The descending part of the duodenum with the head of pancreas overlies the right renal hilum. The left kidney is bordered anteriorly by the left colonic flexure. The left renal hilum is in close anatomic relation to the body of the pancreas and the splenic vessels. The upper pole of the kidneys abuts the adrenal gland, which may cap the kidney or cradle the renal hilum, especially on the left. The posterior aspect of the kidney lies on the psoas muscle [6]. Therefore, it is important to realize that the upper pole lies medially and in a posterior plane relative to the lower pole. Computed tomography (CT) slices are commonly recorded at a right angle to the body, but because of the aforementioned angulation of the kidney, this is not necessarily at right angles to the kidney. Thus, an upper-pole tumor may occasionally appear on CT scan images as a mid-renal tumor. Therefore, for accurate imaging, appropriate adjustment of cross-sectional CT slices is required, taking into account the angulation of the kidney.

Gerota's fascia encloses the kidney, adrenal gland, and perinephric fat. Its layers are fused superiorly, laterally, and medially, but not inferiorly. Classically, the structures of the renal hilum are, from anterior to posterior, a single renal vein, a single renal artery, and the renal pelvis. The hilar region is rotated somewhat anteriorly because of the psoas muscle [7,8].

3.1.1. Arterial system

In approximately 75% of cases, a single renal artery arises bilaterally from the lateral portion of the abdominal aorta immediately caudal to the origin of the superior mesenteric artery. Duplication of renal arteries is more common on the right side (Fig. 1); duplicate arteries are often similar in caliber, with the exception of accessory renal arteries, which occur in approximately 25% of patients. These accessory arteries usually arise from the aorta and commonly subtend the poles. An accessory artery is defined as any supernumerary artery that reaches the kidney. If the artery does not enter the kidney at the hilum (eg, enters the parenchyma at a pole), it is called aberrant. An accessory artery may therefore be aberrant (but is not always so). Accessory arteries to the upper pole are typically smaller in diameter than those to the lower pole. The right renal artery passes behind the inferior vena cava (IVC) and is typically posterior and superior to the left and right renal veins. In approximately 30% of cases, the renal artery is located anterior to the renal vein. The left renal artery is higher than the right [6,9].