3D Image guided Robot-Assisted Partial Nephrectomy with Vincent

Jean-Christophe Berhard, MD, PhD

Urological Surgery and Kidney Transplantation
Pellegrin Hospital
Bordeaux University Hospital.
France

Vincent user voice: 3D image guided robot-assisted partial nephrectomy

Introduction

Kidney cancer is the 6th most common cancer in France, with more than 15,000 new cases in 2018 and an increase in incidence of 1.7% per year in men and 1.4% in women since 1990. This rise mainly concerns localized tumors diagnosed incidentally on imaging.
French and European guidelines recommend partial nephrectomy for all cT1 tumors and cT2 tumors when feasible[5]. Studies show that nephron-sparing surgery (NSS) combines functional benefits with oncological results comparable to radical nephrectomy.
While open surgery has long been the reference, robot-assisted laparoscopic surgery has become preferred, providing better outcomes and reduced perioperative morbidity[1,2] and allowing the use of innovative technical aids.
All these factors have led to a gradual reduction in the length of hospital stays, to the point where selected patients can now be treated as outpatients[3-5], along with the extension of indications for minimally invasive surgery to increasingly complex situations.

Therefore, partial nephrectomy is sometimes indicated in "extreme conditions" combining a complex clinical situation (imperative indication due to a single kidney or pre-terminal renal failure, salvage surgery or anatomical variations) and a complex tumor presentation (multiple tumors, venous invasion, or significant complexity).
We will present the surgical technique of 3D image-guided robotic-assisted partial nephrectomy (30-IGRAPN) and illustrate it through several clinical cases of complex surgery.

3D-IGRAPN technique

Pre-operative planning
A preoperative contrast-enhanced CT scan with acquisition at the cortical, tubular, and urinary phases is an essential preoperative step. Its multi-planar analysis enables a precise study of tumor characteristics, anatomy, and renal vascularization.
It is then possible to create a 3D model using Vincent software (Figure 1) by segmenting the preoperative CT scan to plan the various technical phases of the surgery. This model can be used intraoperatively and displayed in the robotic console (Figure 2) to guide the procedure. This 3D-IGRAPN technique has been shown to improve the quality of surgery[6].
It allows a precise assessment of the renal anatomy and vascularization to plan the management of renal ischemia and the possible opening and reconstruction of the excretory tract.

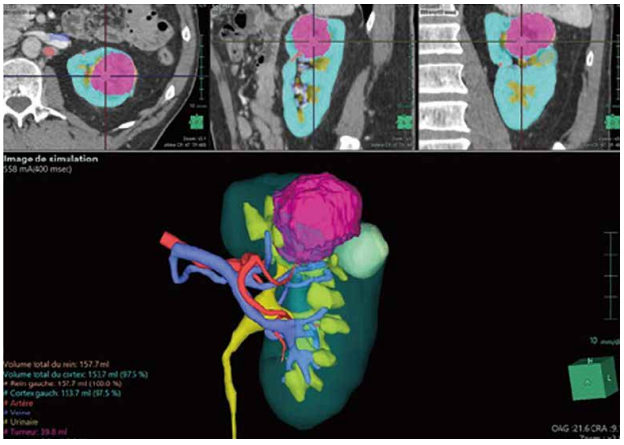

Figure 1 - 3D reconstruction by segmentation of the preoperative CT-scan using Vincent software (Fujifilm)

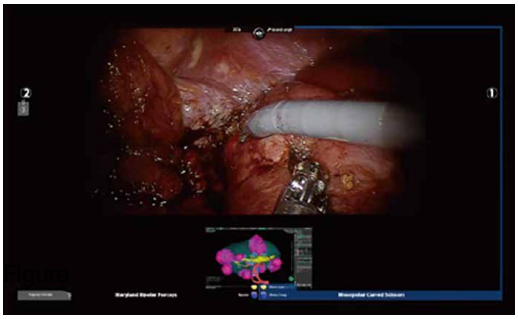

Figure 2 - Console view with Tile Pro function "on" during 3D-IGRAPN

Ischaemia management

The classic partial nephrectomy involves clamping the main renal artery to achieve a bloodless field, but this can cause global renal ischemia. Clamping should be limited to 20-25 minutes to minimize damage to the renal parenchyma, making this method unsuitable for multiple or complex tumors or in "ischemia-sensitive" situations (single kidney, severe chronic renal failure).

Several "zero-ischemia" techniques are available:

1. **Superselective Clamping:** Clamping 3rd or 4th division segmental arterial branches to limit ischemia to the tumor area. Requires precise vascular anatomy understanding, ideally supported by 3D modeling. The ischemic area can be simulated using Vincent (Figure 3) and can be verified with intra-operative metabolic imaging using indocyanine green fluorescence (Figure 4).
2. **Anatomical Tumor Devascularization:** Identification and control of the tumor-feeding arterial branches to progressively release the tumor. This technique is particularly suitable for hilar lesions and extensive excisions like heminephrectomy.
   (Surgical video:)
   https://youtu.be/1Hc9EeDiG9o?si=B-QgZdNA0M3iOfx5)
3. **Off-Clamp Tumorectomy:** Enucleation of the tumor without clamping, using electrocautery for step-by-step hemostasis. Combined with a direct tumor approach and limited kidney release, this simplifies the procedure, reduces operating times, and optimizes preservation of glomerular filtration rate.

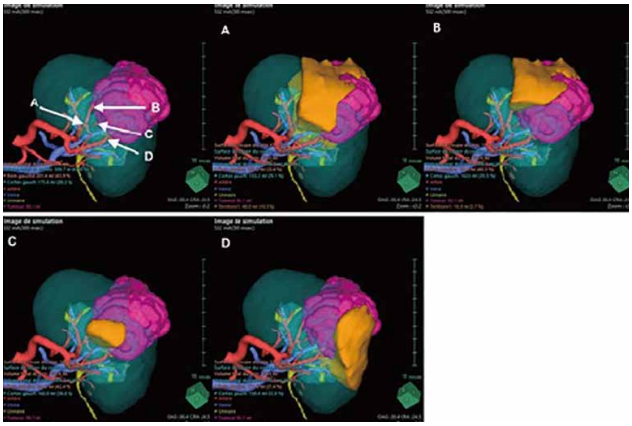

Figure 3 - Simulations of segmental clamping induced ischaemia (orange zone) using Vincent software (Fujifilm)

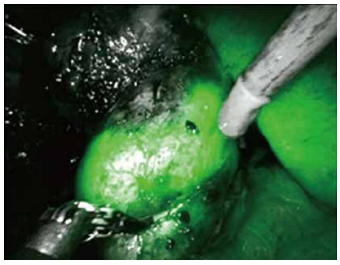

Figure 4 - Superselective clamping and ischemia assessment in fluorescence using indocyanine green injection

Clinical cases: extending indications for minimally invasive nephron-sparing surgery

Salvage tumorectomy after ablative treatment or re-do partial nephrectomy

Ablative therapies (cryoablation, radiofrequency, microwave) offer good functional results and low morbidity for small renal tumors and are therefore increasingly being offered. However, several studies suggest that local oncological control is inferior to that of conservative surgery. Recurrences often require repeat ablation, but location, size, or failures may necessitate salvage surgery. Series published in the literature have highlighted the significant morbidity and complexity of these procedures, due to the fibrosis and inflammation. Given these difficulties, total nephrectomy is usually performed, and an open approach is often chosen.
However, these patients are often frail and suffering from chronic renal failure or have undergone multiple operations. Partial nephrectomy is therefore often imperative to avoid the need for dialysis, and the use of a minimally invasive approach is preferred to reduce the associated morbidity[7].

A 72-year-old patient (UroCCR no.: FR-BOD-P-2043) was incidentally diagnosed with a 5 cm posterior endophytic right renal lesion near the collecting system. He was obese, on anticoagulants tor atrial fibrillation, had chronic renal failure (GFR 34ml/min) and a history of abdominal surgery. Cryoablation was performed off-center. A 4-month follow-up scan revealed the local recurrence of a complex tumor with a RENAL score of 10ph (Figure 5).*
Salvage 3D-IGRAPN surgery was performed using intraoperative ultrasound tor precise tumor delineation. To avoid prolonged clamping of the main renal artery and further GFR deterioration, supra-selective clamping was performed. Surgery lasted 320 minutes, with 100cc blood loss and required opening the excretory tract. The patient was discharged on day 2. Pathology confirmed a clear cell renal cell carcinoma (ccRCC), pT3a, completely resected. Renal function remained stable post-op (GFR 35ml/min) with no recurrence at 5 years.
(Surgical video:)
https://www.youtube.com/watch?v=1Hc9EeDiG9o)

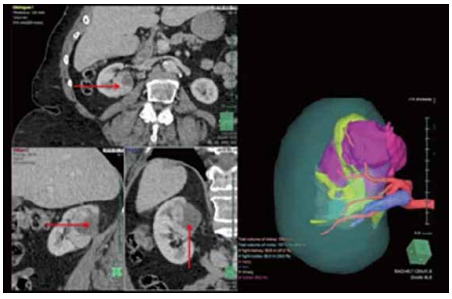

Figure 5 - FR-BOD-P"-2043 patient's preoperative CT scan and 3D model

Multiple tumorectomies

Patients with multiple renal tumors face high risk of contralateral recurrence, making NSS crucial to preserve healthy renal tissue. Such surgeries are often open due to complexity, but minimally invasive methods can reduce morbidity and hospital stay. "Zero-ischaemia" techniques, avoiding prolonged renal artery clamping, are preferred. Tumorectomies may use "off-clamp," supra-selective clamping, or anatomical devascularization based on tumor complexity and location. A 3D model aids in understanding vascular anatomy and tumor location.

A 53-year-old female (UroCCR n°: FR-BOD-P-1997) diagnosed in 2011 with left renal cancer and a synchronous brain metastasis, treated with left radical nephrectomy and stereotactic radiotherapy Pathology revealed pT3a, Fuhrman grade 4 clear-cell renal cell carcinoma. After clinical remission and a breast cancer diagnosis, surveillance was interrupted. Nine years later, multifocal recurrence in the remaining kidney with 10 lesions (10-32 mm) was detected (figure 8). With a GFR of 50 ml/min and negative extension work-up, robot-assisted partial nephrectomies were planned. Surgery, performed without clamping and guided by a 3D model, lasted 284 minutes with 700 cc blood loss and no complications. Pathology showed one pT3a and nine pT1 lesions, all clear-cell with complete resection. Two years later, she was well, with stable renal function (35 ml/min) and no recurrence.*
(Surgical video:)
https://www.youtube.com/watch?v=NH1SEpc_xTA

Figure 8 - Preoperative CT scan and 3D model of FR-BOO-P-1997*

Partial nephrectomy on single kidney. horseshoe kidney or synchronous bilateral tumors

In these situations, NSS is crucial to prevent dialysis, requiring extensive indications for partial nephrectomy and maximum preservation of renal parenchyma. Preoperative planning with 3D models ensures highly selective anatomical devascularization or off-clamp enucleation, avoiding ischemia. Ultrasound must be used to precisely delineate tumor limits, and resection should follow the lesion's enucleation plane to spare healthy tissue. Fluoroscopic control at the end of surgery is used to check the good vascularization of the remaining parenchyma.

A 52-year-old man (UroCCR: FR-BOD-P-2511) underwent a CT scan tor a left flank mass showing bilateral renal lesions: a 20 cm left tumor and a 54 mm right tumor (figure 9). With normal renal function (GFR 85 ml/min) and negative extension work-up, bilateral robot-assisted partial nephrectomy was planned.*

First, a left heminephrectomy with anatomical devascularization was performed, lasting 424 minutes with 400 cc blood loss. Recovery was smooth, and he was discharged on day 2.

Eight weeks later, an off-clamp right partial nephrectomy was performed, lasting 151 minutes with 200 cc blood loss. Postoperatively, a urinary fistula required re-admission on day 3 and was managed with a double-J stent. Both lesions were pT3a ccRCC removed with negative margins. At 3 years' follow-up, he had no recurrence and stable renal function (GFR 58 ml/min).

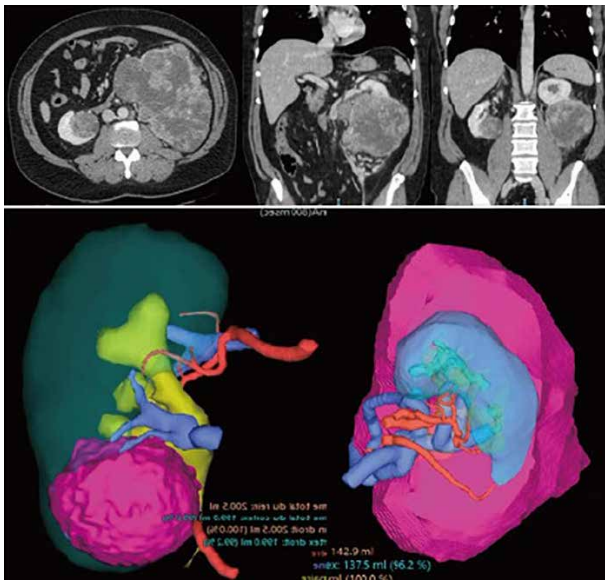

Figure 9 - Preoperative CT scan and 3D models of FR-BOD-P-2511 patient treated for bilateral kidney lesions (A: right kidney; B: left kidney)*

An 85-year-old man (UroCCR no.: FR-BOD-P-3611) with hypertension, anticoagulated tor atrial fibrillation, had a 4.5 cm lesion on a horseshoe kidney incidentally discovered two years ago and managed in another center with an open partial nephrectomy Two years later, a 6 cm isthmic recurrence with thrombotic extension to the vena cava (up to the retrohepatic portion) was diagnosed (figure 10). Renal function was deteriorated (GFR 35 ml/min) and extension work-up was negative. Given his history and renal failure, he was referred for salvage surgery.*

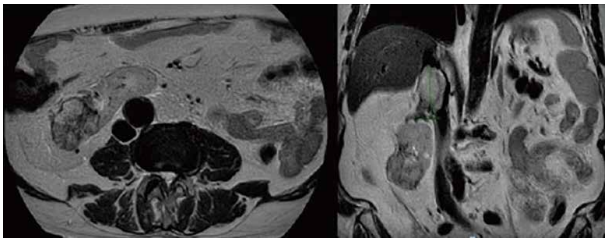

Figure 10 - Preoperative MRI of FR-BOD-P*-3611 patient

A robotic-assisted laparoscopic partial nephrectomy with monobloc vena cava thrombectomy (figure 11) was performed without clamping using the 3D-IGRAPN technique and intraoperative ultrasound. The surgery lasted 11 hours with 2400 cc blood loss and complex anatomical reconstruction. The patient was discharged on day 9 with stable GFR at 32 ml/min.

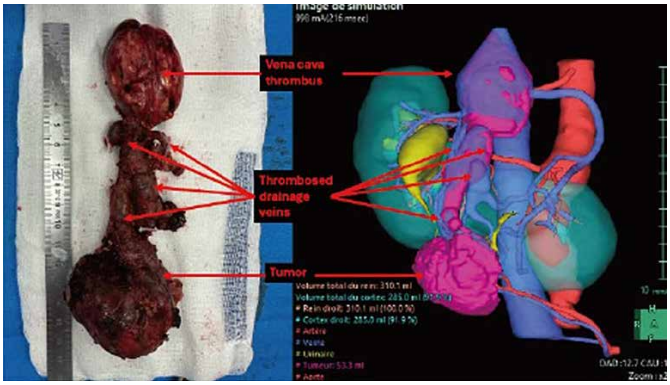

Figure 11 - Side by side comparison of the surgical specimen and preoperative 3D model of FR-BOD-P-3611 patient*

Delayed partial nephrectomy following immunotherapy

Management of metastatic kidney cancer is evolving, with some patients showing complete radiological responses to immune checkpoint inhibitors. Selection of patients suitable for radical nephrectomy to treat residual disease after such responses and its impact on prognosis remain debated. Reports vary on the complexity of these procedures, with some citing increased inflammation from immunotherapy. Despite this, prolonged survival in good responders suggests considering NSS, when feasible, to achieve remission while preserving renal function.

A 55-year-old woman (UroCCR no.: FR-BOD-P-29s6) was diagnosed with intermediate-prognosis metastatic ccRCC and offered systemic treatment with pembrolizumab and axitinib.*

After 18 months, a complete response was observed in metastatic sites and partial response in primary lesions, with four left renal lesions and one large right renal lesion remaining (Figure 12). Management by delayed surgery was therefore offered and consisted in multiple partial nephrectomies on the left kidney and a right radical nephrectomy. The left-side surgery, using the 3D-IGRAPN technique, removed five tumors without clamping, lasted 259 minutes, with 100 cc blood loss. The patient was discharged on Day 1 with a GFR of 47 ml/min. Pathology showed fully resected Fuhrman grade 4 ccRCC.

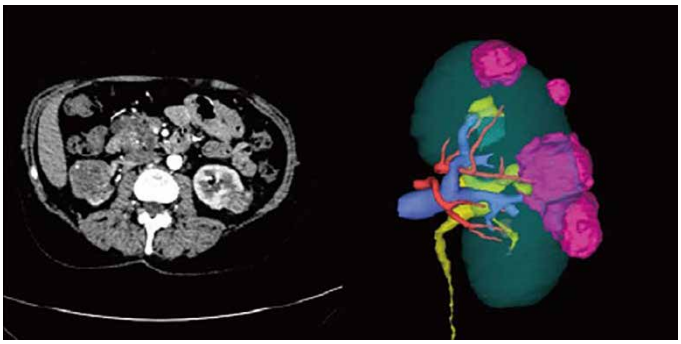

Figure 12 - Preoperative CT scan and 3D model of FR-BOD-P -2956 patient*

Conclusion

While partial nephrectomy is now the gold-standard treatment for small, localized renal tumors, it remains important to remember that it was originally reserved for imperative indications. It is particularly in these situations that the urological surgeon may find himself performing the procedure under "extreme conditions", to preserve the patient's functional autonomy. These surgeries, which should be reserved to expert centers, can be performed using 3D-IGRAPN technique, with the advantage of a reduced morbidity and shorter hospital stays.

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81 Hartwell Avenue, Suite 300, Lexington, MA 02421
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