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Review article

Allograft nephrectomy: Surgical aspects and alternatives

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ABSTRACT

Background: Allograft nephrectomy (AN) is a rare but morbid procedure required after graft failure or neoplasia. We systematically reviewed current knowledge on AN surgical techniques, complications, and alternatives.
Patients and methods: Undertaken to inform the French Association of Urology guidelines on allograft nephrectomy, this review was reported following PRISMA guidelines. PubMed/MEDLINE was searched (January 2000–March 2024) for studies of patients with non-functional first kidney transplants requiring AN or alternative strategies. Case reports, editorials, and non-systematic reviews were excluded.
Results: AN is predominantly performed via an open extraperitoneal approach. For non-functional grafts, consensus is lacking regarding subcapsular versus extracapsular techniques. However, the subcapsular approach reduces operative time, bleeding, and intraoperative complications, though overall morbidity data remain conflicting. The surgical approach does not impact alloimmunization. Regarding arterial embolization, protocols are not standardized. Yet, it achieves >80% success with lower mortality and morbidity than AN. Its main complication is post-embolization syndrome, potentially leading to secondary AN. Embolization prior to AN effectively reduces intraoperative bleeding and operative time.
Conclusion: The extraperitoneal subcapsular approach appears to be the safest surgical option. Arterial embolization is a valuable alternative or adjuvant strategy to AN in managing graft intolerance syndrome after graft failure.

1. Introduction

Allograft nephrectomy (AN) is a surgical procedure occasionally required during the management of kidney transplant recipients; its indications, timing, and techniques vary between centers. There is greater consensus for oncologic indications: when a tumor is present, whether the graft is functional or not, AN may be indicated to achieve local disease control [1–3]. Conversely, in case of graft failure, the question of maintaining the graft in situ and/or continuing residual immunosuppression remains insufficiently codified, with significant heterogeneity in practices. This situation is relatively common, since graft dysfunction is responsible for 40% of returns to dialysis after kidney transplantation [4,5].

In this context, AN is often described as a technically demanding procedure, prone to hemorrhagic and infectious complications, which explains why some teams are cautious about adopting a systematic approach. The morbidity of AN has a strong variability in the literature (5 to 59%) [6], as does mortality (0 to 38%) [6,7].

Beyond the strictly medical risk-benefit balance, graft loss and a return to dialysis represent a major event in a patient's life that can affect

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treatment adherence and quality of life [7]. The specific psychological impact is poorly documented and rarely taken into account in decision-making algorithms. A prospective single-center study comparing the outcomes of early versus late nephrectomy (more than three months after transplantation) reported seven cases of depression in the early nephrectomy group and three cases of psychosis [8].

In this context, the Transplantation Committee of the French Association of Urology, in multidisciplinary collaboration with the Francophone Transplantation Society, has structured a project aimed at clarifying the indications and timing of AN, the immunological impact of immunosuppressant management, the technical aspects of surgery, and conservative alternatives, resulting in French recommendations published in 2025 [9].

The aim of this work is to detail the results of a literature review concerning the surgical aspects of AN and alternative treatments, particularly endovascular approaches, in order to provide a practical summary useful for clinical decision-making.

2. Material and methods

2.1. Guideline context

This systematic review was undertaken as part of the comprehensive clinical guideline development process on allograft nephrectomy by the Transplantation Committee of the French Association of Urology (CTAFU) [9]. While the practical guidelines have been published separately, the present manuscript details the exhaustive literature review and data synthesis conducted to specifically address the question regarding surgical techniques, complications, and endovascular alternatives.

This literature review was reported according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Figs. 1 and 2).

2.2. Sources of research strategies

A preliminary review of available national/international recommendations and texts was conducted to identify practice frameworks. The PubMed/MEDLINE search covered the period from January 2000 to March 2024, with no age restrictions, and was limited to publications in French or English.

2.3. Eligibility criteria

Included studies focused on patients with a non-functional first kidney transplant who were candidates for AN or a conservative/alternative strategy (including endovascular approaches), regardless of the time since transplantation and the clinical context. Eligible study types included meta-analyses, randomized controlled trials, prospective non-randomized studies, and retrospective studies. Non-systematic general reviews, editorials, clinical cases/case studies, and conference proceedings were excluded. AN for oncological reasons or emergency AN (bleeding, graft thrombosis) following kidney transplantation were not included.

2.4. Study selection

The selection was initially performed by the methodologist (DK) based on these criteria after abstract screening. The selection was independently validated by the steering committee (TC, AF, AG, TP, ADB). The articles selected at this stage were then evaluated in full text to confirm eligibility. Any disagreements were resolved through discussion within the group.

2.5. Data synthesis

Given the expected heterogeneity of populations, indications,

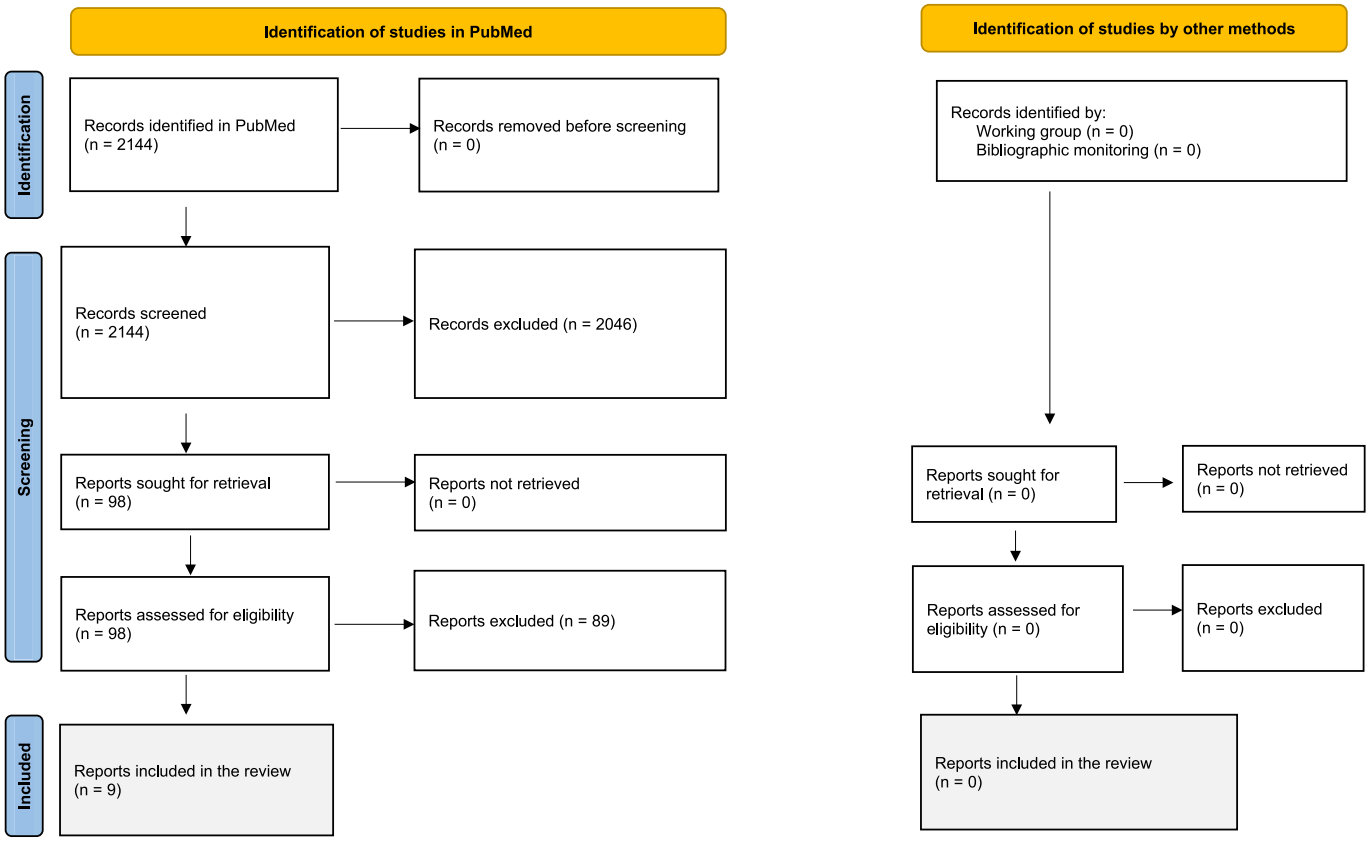

Fig. 1. allograft nephrectomy Prisma chart.

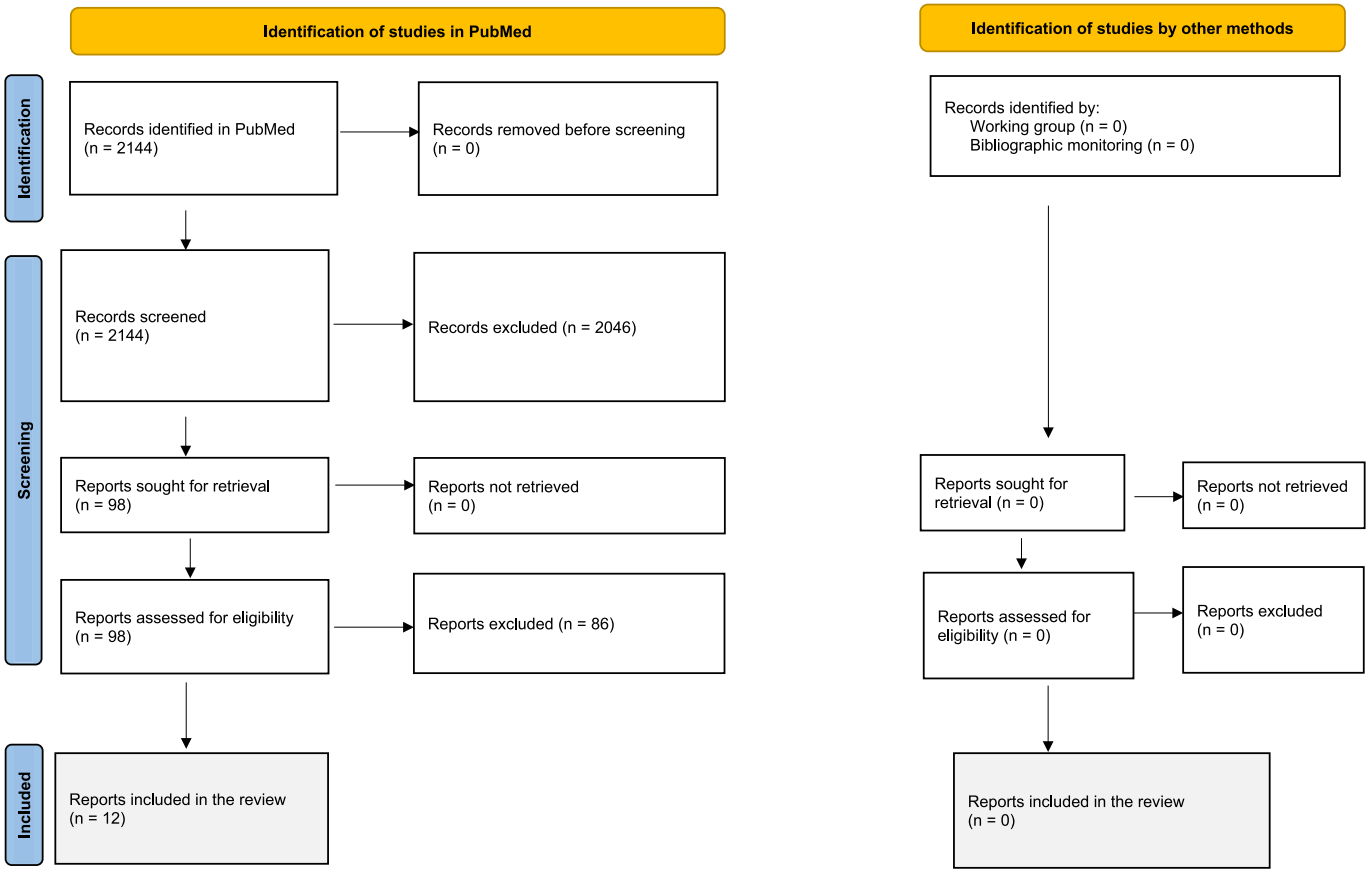

Fig. 2. allograft embolization Prisma chart.

techniques, and reported endpoints, results were synthesized descriptively.

3. Results

1. Allograft nephrectomy

Regarding AN surgical technique, 9 studies were included (Table 1).

Table 1
surgical approach: included studies.

Type of study	Found on SS or Cochrane websites	Selected by the algorithm on PubMed	Suggested by the WG
Recommendations		[Lubetzky et al. 2021]	
Comparative studies		[Touma et al. 2011] [Mazzucchi et al. 2003]	
Observational studies		[Freitas et al. 2015] [Mang et al. 2024]	
Other		[Rubinz et al. 2019] [Vavallo et al. 2012] [De Rosa et al. 2011] [Zomorrodi and Buhluli 2008]. [Ghinolfi et al. 2005].	

3.1. Surgical approach (Fig. 3, Table 2)

Among the original studies analyzed, 7 out of 9 describe an extraperitoneal approach corresponding to the standard approach for reopening the transplant site [10–17]. Only one retrospective study reported a transperitoneal AN: Rubinz et al. ($n = 38$), using a technique involving a peritoneal window [18]. The authors report acceptable morbidity with an average operating time of 97.1 min, average blood loss of 172.5 mL, an average hospital stay of 3 days, an overall complication rate of 24%, a transfusion rate of 15.7%, a risk of reoperation of 5.6%, and a risk of serious adverse events according to Clavien and Dindo III of 5.2%. No direct comparison with the extraperitoneal approach was available in the literature.

3.2. Extracapsular versus subcapsular

The intracapsular or subcapsular approach involves opening the graft capsule and removing the parenchyma, leaving the capsule in place and preserving a vascular stump of the graft. In the literature, regarding the management of the residual cavity several approaches are described. Ghinolfi et al. perform an obliteration of the renal capsule using three running sutures (Vicryl 3/0) [19]. De Rosa et al. suggest the use of TachoSil to treat bleeding in the residual cavity during intracapsular nephrectomy [20]. In Zomorrodi et al. technique, diluted betadine was instilled inside the capsule and a drain inserted in the residual cavity [21]. The extracapsular approach involves dissection in the plane of the extended nephrectomy, removing the graft with its capsule, leaving only the anastomotic vascular stumps. For suspected graft neoplasia, an extracapsular approach is recommended in order to optimize excision and cancer control in accordance with current French guidelines [1,3,9]. However, there is no consensus on using a subcapsular versus

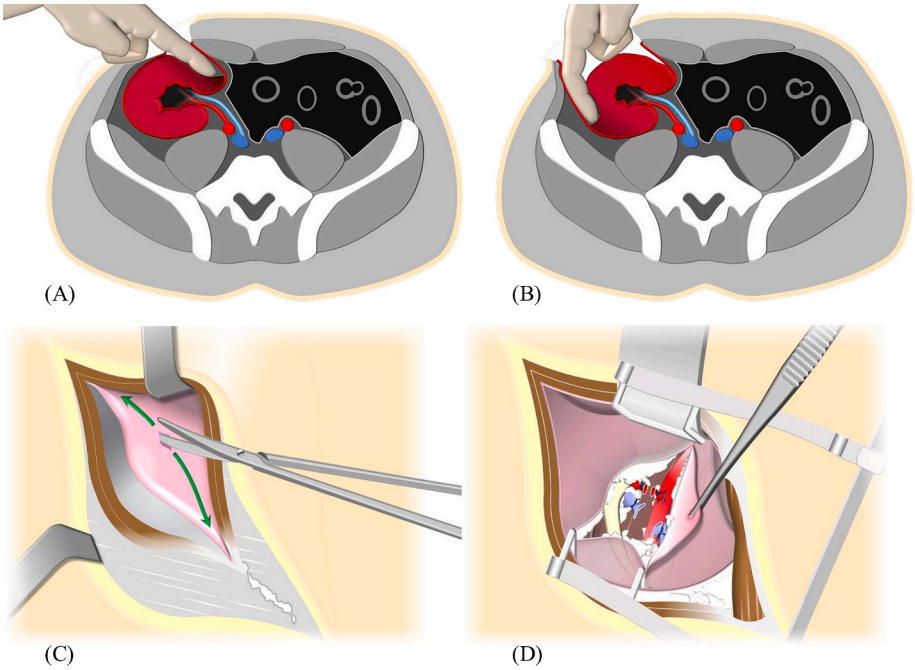

Figure 1.

Fig. 3. allograft nephrectomy. (A) (B): Extraperitoneal and subcapsular allograft nephrectomy with dissection between the capsula and the parenchyma; (C) (D): intraperitoneal and extracapsular allograft nephrectomy with opening of the peritoneum in order to dissect and section the vessels near their origin.

Table 2
: Surgical outcomes (ICAN: intracapsular allograft nephrectomy; ECAN: extracapsular allograft nephrectomy; PRA: panel reactive antibodies; NA: non applicable; NS non significant).

Study	Design	n	Surgical approach	Operative time	Complications	mortality	transfusion	PRA	Mean hospital stay
Touma et al. 2011 [11]	Retrospective Comparative	67	23 intracapsular (ICAN) vs 44 Extracapsular (ECAN)	110.9 vs 130.4 min for ICAN vs ECAN (p = 0.02)	2.2% morbidity vs 15.9% for ICAN vs ECAN (NS)	0% vs 2.2% for ICAN vs ECAN (NS)	0 vs 15.0% for ICAN vs ECAN (NS)	NS	NA
Mazzucchi et al. 2003 [14]	Retrospective comparative	47	30 intracapsular (ICAN) vs 17 Extracapsular (ECAN)	109.4 vs 125.3 min for ICAN vs ECAN (NS)	13.3% major complication vs 17.6% for ICAN vs ECAN (NS)	NA	53.3% vs 35.3% for ICAN vs ECAN (NS)	NA	NA
Freitas et al. 2015 [22]	Retrospective comparative	72	43 intracapsular (ICAN) vs 29 Extracapsular (ECAN)	63.9±30.9 vs 62.0±28.3 min for ICAN vs ECAN (NS)	23.3% major complication vs 20.7% for ICAN vs ECAN (NS)	NA	NA	%PRA variation (−1.2 ± 10.6 ICAN vs −0.5 ± 15.9 ECAN; P = 0.8)	14.5±16.2 vs 10.3 +/− 11.3 for ICAN vs ECAN (NS)
Mang et al. 2004 [12]	Retrospective comparative	195	117 intracapsular (ICAN) vs 36 Extracapsular (ECAN)	138 vs 140 min for ICAN vs ECAN (NS)	Complication ≥ IIIb 8.5% vs 22.9% for ICAN vs ECAN (p 0.034)	NA	23% vs 8% for ICAN vs ECAN (NS)	NA	10 vs 13 for ICAN vs ECAN (NS)
Rubinz et al. 2019 [18]	Retrospective observational	38	intraperitoneal	97.1 ±28.9 min	27.7% (5.2% clavien III)	0	15.7%	NA	3.08 ±1.7
Vavallo et al. 2012 [13]	Retrospective comparative	89	32 intracapsular (ICAN) vs 57 Extracapsular (ECAN)	126.5 vs 145 min for ICAN vs ECAN (NS)	21% vs 31% for ICAN vs ECAN (NS)	NA	290 mL vs 300 mL for ICAN vs ECAN (NS)	NA	7.6 vs 13.8 for ICAN vs ECAN (P 0.01)
De Rosa et al. 2011 [20]	Retrospective comparative	25	10 ICAN (post embolization) vs 15 ICAN + tacchosyl	NA	NA	NA	NA	NA	6.7 vs 8.3 for ICAN + Tacchosyl vs ICAN
Zomorrodi and Buhluli et al. 2008 [21]	Retrospective Observational.	32	25 (ICAN) vs 7 emergency ECAN post transplant	40 min (ICAN)	NA	0 vs 57% for ICAN vs emergency ECAN	NA	NA	NA
Ghinolfi et al. 2005 [19]	Retrospective observational	9	ICAN with obliteration of the renal capsule	NA	22% (fever)	0	NA	NA	NA

extracapsular approach for allograft nephrectomy of a nonfunctional graft.

The literature suggests a link between the post-transplant interval and the technique used. In a descriptive series by Emiroglu et al., it was reported that early allograft nephrectomy(< 6 months, $n = 21$) was performed via an extracapsular approach, while late allograft nephrectomy was performed via a subcapsular approach. [10]. This practice probably reflects the increasing difficulty of extracapsular dissection in a late setting.

Comparative data remain inconsistent regarding the overall superiority of either approach in terms of surgical outcomes and morbidity [11–14,22]. The intracapsular approach appears to be associated with a reduction in operating time, with a statistically significant difference in the comparative study by Touma et al. [12]. In the studies by Vavallo et al. and Mazzucchi et al., it was more of a trend without significance. [13,14]. A reduction in severe complications has been suggested in some studies. Mang et al. reported fewer major surgical complications (Dindo and Clavien > IIIb) in the intracapsular group, without providing exhaustive details on the nature of the events [12]. Conversely, other series did not show any significant difference except for a longer stay in the extracapsular group in Vavallo et al. [13]. However, the results are contradictory regarding blood loss and transfusions. Touma et al. reported a significant decrease in blood loss with the intracapsular approach [11], while Mazzucchi et al. reported significantly greater blood loss in the intracapsular group [14]. In these two studies, no clear difference was reported regarding the use of transfusions.

3.3. Immunological results and prospects for re-transplantation

No robust differences in allosensitization between extracapsular and intracapsular approaches have been described in the available studies, particularly with regard to panel reactive antibodies progression [11,22]. The percentage of patients relisted was similar between the two techniques in two retrospective studies reported by Touma et al. and Freitas et al. However, these results should be interpreted with caution due to methodological limitations, particularly the retrospective nature of the studies and the heterogeneity of immunosuppression and indications [11,22].

3.4. Minimally invasive graft nephrectomy (pure laparoscopy and robotic laparoscopy)

Minimally invasive AN (pure laparoscopy and robotic laparoscopy) has been described in the literature mainly in the form of case reports and small series, which do not allow conclusions to be drawn about superiority in terms of safety or efficacy compared to the open approach. Three case reports describe pure laparoscopic AN. The approach was transperitoneal in these publications. The main complication reported was intraoperative blood loss; no deaths were described.

Two case series (15 and 5 patients) and one case report have described robot-assisted laparoscopic AN. The approach was transperitoneal in all cases. In the series by Abdul-Muhsin et al. [23], two conversions were necessary (severe adhesions and injury to the iliac vessels: artery and vein). Postoperative complications reported included Clavien-Dindo grade II events ($n = 3$), grade III events ($n = 1$), and one death (grade V) due to pulmonary embolism at three weeks. In the series by McCabe et al. [24], three intraoperative complications were reported, including two bladder fistulas and one difficult-to-control venous hemorrhage. The median blood loss was 188 mL (40–550), with no intraoperative transfusion or conversion. Two deaths were reported at follow-up: one myocardial infarction at 5 months and one death of undetermined cause at 2.5 months.

3.5. Pediatric cases

Only one pediatric study evaluating AN after graft failure was selected, published by Zerouali et al. in 2004 [25]. Patients (included between 1977 and 1999) were divided into three groups according to the main cause of graft loss of function: vascular thrombosis (group 1, $n = 19$), acute rejection (group 2, $n = 22$), and chronic rejection (group 3, n = 22). The time between transplantation and graft loss was 0 to 1 month in group 1, 1 month to 1 year in group 2, and more than 1 year in group 3. Extracapsular AN was performed in group 1, while subcapsular AN was performed in groups 2 and 3. The median time between graft loss and allograft nephrectomy was 30 days (group 2) and 97 days (group 3). No intraoperative deaths were reported. Postoperative complications mainly included parietal infections ($n = 5$), eventrations (n = 5), deep vein thromboses ($n = 3$), febrile episodes ($n = 6$), and pneumonia ($n = 1$). The mean length of hospital stay was 19.5 days. The study did not report any specific comparative analysis based on the surgical approach.

2. Graft arterial embolization

Twelve publications were selected for our analysis (Table 2 **and** Table 3).

3.6. Technical aspects

The percutaneous embolization technique used in the studies was not standardized. The procedure could be performed under local anesthesia [15,26]. The use of prophylactic antibiotics or corticosteroids has been described but did not appear to be systematic [27,28].

In the studies, embolization was performed percutaneously via the femoral artery. Several materials can be used: ethanol [15], polyvinyl alcohol [26,28], occlusion balloon [15,27,28], porcine gelatin sponge [15], Gelfoam™ slurry [29], microspheres [27,29], various types of coils (steel coils, metal coils, vascular coils, Tornado™). In most cases, a control angiography confirmed complete renal exclusion.

3.7. Clinical results (Table 4)

In 2000 Gonzalez et al. presented the results of their retrospective study: 33 patients underwent an arterial embolization for a graft intolerance syndrome. The treatment was effective in 28 patients (85%). Twenty patients presented with a post embolization syndrome (61%)

Table 3
arterial embolization: included studies.

Type of study	Found on SS or Cochrane websites	Selected by the algorithm on PubMed	Suggested by the WG
Recommendations	[BTS 2023]	[Fernander Fresnedo et al. 2009]	
Systematic reviews		[Takase et al. 2018]	
Comparative studies		[Neschis et al. 2007]	
Observational studies		[Fantoni et al. 2021], [Cofan et al. 2002], [Panarese et al. 2021], [Garcia-Padilla et al. 2020], [Yeast et al. 2016], [Al-Geizawi et al. 2015], [Krause et al. 2008], [Delgado et al. 2005]	
Other		[Altar et al. 2003] [Gonzales-Satue et al. 2000] [Jacobs et al. 2022]	

Table 4
: arterial embolization alternative to AN:outcomes (PRA: panel reactive antibodies; NA: non applicable; NS non significant).

Study	Design	n	Intervention	success	complication	Post embolization syndrome	Second embolization	Allograft nephrectomy	PRA	Mean hospital stay (days)
Gonzalez et al. 2000 [30]	Retrospective observational	33	Arterial embolization	85%	NA	61%	6,1%	15%	NA	5
Cofan et al. 2002 [16]	Retrospective observational	30	Arterial embolization	80%	NA	47%	10%	20%	NA	NA
Atar et al. 2003 [17]	Retrospective observational	26	Arterial embolization	92% (technique) 92% (clinical)	7.7%	88%	3.8%	3.8%	NA	NA
Delgado et al. 2005 [15]	Retrospective observational	48	Arterial embolization	65%	83%	60%	16.7%	22.9%	NA	NA
Takase et al. 2018 [32]	Literature review	189	Allograft nephrectomy (n = 2232) vs arterial embolization (n = 189)		morbidity (1.2%; 95% CI 0.7–2.1 vs. 18%; 95% CI 13–26)	68%	NA	20%	NA	NA
Garcia-Padilla et al. 2020 [26]	Observational retrospective	12	Arterial embolization	83.3%	25%	8.3%	0	16,7%	NA	5.5 (1–24)
Fantoni et al. 2021 [27]	Observational retrospective	15	Arterial embolization	73%	27%	20%	6.7%	26.7%	NA	8

and 5 patients underwent a secondary AN (15%) [30]. In the study by Cofan et al. (n = 30), embolization resulted in prolonged symptom resolution in 80% of cases (24/30). Symptomatic recurrence occurred in 6 patients, leading to AN, and no major complications or deaths were observed [16]. Atar et al. reported 26 embolizations (25 patients) with a technical success rate of 92% (24/26) and a clinical success rate of 92% (24/26). Two major complications were observed (emphysematous pyelonephritis requiring allograft nephrectomy and drained inguinal abscess). A secondary AN was performed in one patient at 3 months due to persistent clinical failure [17]. In the retrospective cohort study by Delgado et al. (149 patients returning to dialysis; immunosuppression discontinued), graft intolerance syndrome occurred in 37% (55/149) of patients, mainly within the first 6 months and almost always within 24 months after failure. Embolization was performed in 48 patients, with clinical success after one or more sessions in 65% of cases (31/48); a second embolization was necessary in 8 patients. No deaths or severe complications were reported. Secondary AN was required in 22% (11/48) due to persistent syndrome (n = 8) or graft infection (n = 3) [15].

According to the Spanish guidelines for the management of kidney transplant failure, graft embolization is presented as an alternative to AN with lower morbidity and mortality rates [31].A systematic review by Takase et al. (n = 2421; AN n = 2232, embolization n = 189) showed that percutaneous embolization was associated with significantly lower 30-day mortality (0.1%; 95% CI 0.1–0.5) than AN (4%; 95% CI 2–7), as well as lower overall morbidity (1.2%; 95% CI 0.7–2.1 vs. 18%; 95% CI 13–26, respectively). On the other hand, embolization was associated with a frequent post-embolization syndrome, reported in 68% of cases (pain, fever, myalgia), which was generally controlled by symptomatic treatment [32].

Most recent studies supported the previous results: Garcia-Padilla et al. (n = 12; 2012–2018) observed a median delay in the onset of intolerance syndrome of approximately 6 months after resumption of dialysis (range 0.6–13). The main complication was a hematoma at the puncture site (3/12) and a single case of post-embolization syndrome (1/12), which resolved with corticosteroids. Two patients required secondary AN (persistent renal flow and symptoms). The reported success rate was ≥83.3%. [26]. The last study published by Fantoni et al. presented the results of arterial embolization in patients presenting with graft intolerance syndrome: 15 patients were treated, and 4 of them needed a secondary AN [27].

None of the previous studies presented results regarding immunological results after arterial embolization.

3.8. Pediatric population

Krause et al. described in their study grafts failures in 18 children: 11 patients presented with a graft intolerance syndrome [28]. Three patients underwent drug treatment, one patient underwent AN, and 7 patients underwent graft embolization for graft intolerance symptoms. Six of the 7 patients presented complete resolution of the symptoms, one patient needed a secondary embolization, and 4 patients underwent a secondary AN, no major complication occurred [28].

3.9. Embolization prior to AN (Table 5)

The most recent studies are evaluating the efficiency of the graft arterial embolization prior to AN. De Rosa et al. aimed to describe the use of TachoSil to treat bleeding in the residual cavity during intracapsular nephrectomy, after all patients had undergone an arterial embolization prior to the AN [20]. In a retrospective comparative study Neschis et al. evaluated the results of AN with embolization prior to surgery versus AN without embolization. Embolization performed immediately before AN (13 cases) was associated with a significant reduction in blood loss (198 mL vs. 465 mL; p = 0.035) and transfusion requirements (0.31 vs. 1.85 RBC units within 48 h; p = 0.008), without any increased risk of major complications [33]. Two other studies on small cohorts published by Yeast et al. and by Al-Geizawi et al. agree on the benefit of the embolization before AN regarding blood loss [29,34]. These data were supported by a study on a larger cohort published by Panarese et al. who also demonstrated the benefit of embolization prior to AN regarding the hemoglobin variation (−1.665 vs −0.7872) and the operative time (93.46 vs 64.62) [35]. Jacob et al. published in 2022 a retrospective study supporting the previous results [36].

4. Discussion

Allograft nephrectomy is a key procedure in the management of non-functional kidney transplants, but its indication and modalities must be individualized according to the clinical context, surgical risk, and retransplantation plan. In cases of suspected or confirmed graft neoplasia, extracapsular allograft nephrectomy is the recommended approach to achieve complete oncologic excision, in accordance with French guidelines [1,3].

We did not include emergency AN performed in case of graft thrombosis or hemorrhagic complications, as the procedure is usually performed as an emergency. The surgical approach is usually the same as for kidney transplantation: extraperitoneal and extracapsular since there are no capsular adhesions shortly after transplantation and local

Table 5
: Embolization prior to AN (PRA: panel reactive antibodies; NA: non applicable; NS non-significant).

Study	Design	n	Intervention	Operative time	Blood loss	transfusion	complication	PRA	Mean hospital stay
Neschis et al. 2007 [33]	Observational retrospective	26	Embolization + AN [13] vs AN [13]	150 vs 113 min; p = NS	198 vs 465 mL; p = 0,035	0,7% vs 2,3%; p = 0,03	NA	NA	NS
Yeast et al. 2016 [29]	Observational retrospective	16	Embolization + AN [9] vs AN [7]		198 vs 465 mL; p = 0,035	0,7% vs 2,3%; p = 0,03	NA	NA	5,4 vs 3,9 days; p = 0,01
Al-Geizawi et al. 2015 [34]	Observational retrospective	26	Embolization + AN [13] vs AN [13]	192 ± 114 min à 141 ± 38 min; p NS	375 ± 530 mL à 100 ± 162 mL; p NS	3,36 ± 4,8 units to 0,23 ± 0,44 units; p NS	NA	NA	8,5 ± 9 days to 5,5 ± 3 days; p NS
Panarese et al. 2021 [35]		66	Embolization + AN [25] vs AN [38]	(93.46 vs 64.62)	hemoglobin variation (−1.665 vs −0.7872)			NA	
Jacob et al. 2022 [36]		80	Embolization + AN (54) vs AN [25]	142 ± 43 min vs 202 ± 111 min; p 0.001	266 ± 292 mL vs. 495 ± 689 mL; p 0.04	0.5 ± 0.8 units vs 1.6 ± 2.6 units; p 0.004	11% vs 35% p 0.02	NA	4.3 ± 2 vs 9.3 ± 9.4 days; p 0.02

inflammation is minimal [37]. Outside the tumor or emergency context, reported practice suggests a pragmatic selection of techniques: the extracapsular approach is more frequently used in early AN, while the intracapsular approach is more often preferred in late AN. In the available comparative series, the extracapsular approach appears to be associated with an increased risk of surgical complications compared to the intracapsular approach, although these results may be influenced by indication bias and the more urgent/inflammatory nature of the cases.

AN can be performed via a retroperitoneal or intraperitoneal approach, with no robust comparative evidence to formally recommend a single approach.

Arterial embolization for graft intolerance syndrome is reported as a reliable alternative to allograft nephrectomy in selected patients, with success rates typically >80%, lower mortality (≈0.1% vs 4%) and lower morbidity (≈1.2% vs 18%) [32]. This technique carries a 60–70% risk of post-embolization syndrome (fever, myalgia, pain, nausea), may require a second embolization in 6–16% of cases, and can lead to secondary allograft nephrectomy in about 20% of patients [15,27,32]. Embolization of the graft artery prior to AN may be considered as an adjunctive strategy to reduce blood loss and potentially shorten operative time, particularly in situations with a high risk of bleeding, but this is based on limited evidence. One of the limitations of embolization remains vascular access: it is well known that due to kidney failure and other pathologies (diabetes, obesity, smoking, etc.) those patients are more likely to present with vascular calcifications limiting the access for this technique [38]. Based on our review, we were unable to determine whether there was an immunological difference between embolization and AN.

In case of allograft failure, it seems important to present patients with all treatment options, including their advantages and potential complications. The patient's general condition must also be considered. Elderly patients with multiple comorbidities may not be eligible for surgical treatment due to anesthesia-related concerns. Prospective multicenter studies standardizing indications, timing, endpoints, and immunosuppression strategies are needed to refine recommendations and improve the comparability of results.

Finally, based on the available evidence and the working group discussion, we concluded:

1) In patients with graft intolerance syndrome, intracapsular transplant nephrectomy reduces the operating time, intraoperative bleeding and intraoperative vascular complications [11,12] (Level of Evidence (LoE) 4);
2) Findings are conflicting concerning the comparison of morbidity between extracapsular and intracapsular transplant nephrectomy [11,12] (LoE 4). Conversely, there is no difference in the impact on alloimmunization [11] (LoE 4);
3) The literature contains several case reports on laparoscopic and robotic-assisted transplant nephrectomy [23,24,39–41]that do not allow us to conclude whether it is more beneficial or safer than the open approach.
4) Compared with transplant nephrectomy, embolization has lower mortality (0.1% vs. 4%) and morbidity rates (1.2% vs. 18%) [32] (LoE 3);
5) However, post-embolization syndrome (fever, myalgia, pain, nausea) occurs in 60–70% of patients [32] (LoE 3), transplant nephrectomy is required in 20% of patients after embolization [32] (LoE 3), and a second embolization is needed in 6–16% of patients [15,27] (LoE 4);
6) The main complications of embolization are: graft abscess [17,28,30] (LoE4) [32] (LoE 3), graft infection [32] (LoE 3), and puncture site hematoma [26] (LoE4) [32](LoE 3);
7) Embolization of the graft artery before transplant nephrectomy appears to reduce perioperative bleeding and operative time [29,33–36] (LoE 4);
8) There are no data on the impact of embolization on immunization and access to retransplantation.

5. Conclusion

In case of graft failure, AN is a key procedure for our patients. The extraperitoneal subcapsular open laparotomy technique is commonly preferred for non-oncological indications to minimize intraoperative risks, though overall morbidity comparisons remain conflicting. Minimally invasive techniques have been described in few cases but the lack of publications on these procedures does not allow us to recommend them. Arterial embolization is an alternative to AN with a lower mortality and morbidity but is frequently associated with post-embolization syndrome and required sometimes a second treatment or a secondary AN.

5.1. *What this study adds*

This systematic review consolidates the fragmented literature regarding the surgical and endovascular management of non-functional kidney allografts. It clarifies that while the extraperitoneal subcapsular approach is generally favored for late nephrectomies to reduce operative time and blood loss, overall morbidity outcomes remain highly variable. Furthermore, this study highlights arterial embolization as a highly effective, lower-morbidity alternative or adjunct to surgery for graft intolerance syndrome, despite the frequent occurrence of post-embolization syndrome. By comprehensively mapping these strategies, this review provides a much-needed, evidence-based foundation to guide personalized clinical decision-making and inform standardized practice guidelines.

Declaration of competing interest

The authors declare no conflicts of interests related to this article.

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