Wilms tumor: a review of current surgical controversies

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Abstract: Overall survival (OS) for children with Wilms tumor (WT) currently stands at around 90%. This is markedly improved from the survival rates of around 30% reported in the middle of the last century. This improvement is due to the development of multimodal treatment for this disease, based on the evidence yielded through international collaboration on trials conducted by the Société Internationale d'Oncologie Pédiatrique (SIOP) and the Children's Oncology Group (COG). In this article, we review some of the current surgical controversies surrounding the management of WT.

Keywords: Wilms tumor (WT); nephroblastoma; nephron sparing surgery (NSS); minimally invasive surgery; lymph node sampling

Introduction

Wilms tumors (WTs) account for over 95% of all kidney tumors in children (1), and the overall survival (OS) rate currently stands at over 90%. This remarkable achievement is in many ways due to international collaboration on trials conducted by the Société Internationale d'Oncologie Pédiatrique (SIOP) and the Children's Oncology Group (COG) which supplanted the National Wilms Tumor Study Group (NWTSG) in 2002 (2). Although these two groups have a slightly different approach, they have provided a large body of evidence-based knowledge that allows for accurate risk stratification and management of WT.

In this article, we will review some of the surgical controversies in the management of WT, with special focus on the utility of minimally invasive and nephron-sparing surgical techniques.

Nephron-sparing surgery in non-syndromic unilateral WT

Traditionally, nephron sparing surgery (NSS) is indicated in children with bilateral WT, a single kidney, or an abnormal contralateral kidney, as well as in children at high risk of metachronous tumors, such as those with genetic predisposition syndromes, those who are less than a year old, and those with nephroblastomatosis (3).

Recently, the possibility that NSS should be considered in children with unilateral disease has come to the fore. As the survival rate for WT exceeds 90%, reports of increased treatment-related morbidity and mortality 25 years from diagnosis have come to light (4). These morbidities include congestive heart failure due to doxorubicin exposure and lung radiation (5), and increased rates of arterial hypertension compared to healthy controls (6), amongst others. Particularly, patients with WT may be at increased risk for renal dysfunction over time, as surgery itself removes functional renal parenchyma (along with the neoplasm) and certain chemotherapeutic agents and radiotherapy are directly nephrotoxic (6,7). The long-term benefits of preserving renal parenchyma need to be balanced against the possibility that NSS will adversely affect short-term outcomes, specifically with regards to overall and event-free survival (EFS) in patients with WT.

Simply put, the ultimate goal of NSS is the preservation of renal function without compromising complete tumor resection (8). The SIOP WT-2001 protocol allows for NSS for polar or peripherally non-infiltrating tumors, which can be resected with clear margins. The report published in 2014, detailing the SIOP 2001 experience with NSS for unilateral WT for that 'NSS is not only feasible but also safe providing recommendations on suitable tumor configuration are adhered to. Although the low (4%) relapse rate did not contribute to mortality, one must remain aware of the potential pitfalls that could threaten the patient.' (9).

The data on long-term renal function in non-syndromic unilateral WT is mixed: Cozzi *et al.* found 43% of adults under the age of 30 had mild renal function loss following nephrectomy for WT as children (10), whereas long-term data on patients treated in the NWTSG shows a cumulative incidence of around 0.7% only (11). Unfortunately few studies evaluate the deterioration of renal function beyond the development of end stage renal disease (ESRD) and it is possible that when more refined surrogates of renal function are investigated, the incidence of renal dysfunction will be found to be much higher (7). Similarly, the duration of available monitoring may not be long enough to detect the early development of chronic renal insufficiency with the expected decrease in nephron mass experienced with aging. The pediatric patient population is dramatically different from adults, particularly in terms of life expectancy. In adults, evidence shows that NSS for small, early-stage kidney cancers may reduce the incidence of long-term deterioration in renal function, as well as improve long-term cardiovascular and overall health (12,13). Data have shown that children undergoing NSS have decreased rates of arterial hypertension compared to those undergoing RN, with equal rates of local recurrence (14). With adequate follow-up into adulthood, the benefit of NSS in children may be even more striking.

Establishing feasibility

An attempt to determine the suitability of a tumor for NSS should be made pre-operatively, based on cross-sectional imaging. That said, Davidoff *et al.* found that the resectability of large tumors cannot always be predicted by pre-operative imaging, and in the case of bilateral tumors, NSS should always be attempted in an effort to avoid bilateral nephrectomies. Changes induced through neoadjuvant chemotherapy may also allow tumors that

initially appear non-amenable to NSS to become more favorable. In their series they successfully completed NSS in all patients in whom they set out to do so, although complications such as urine leak, urinoma, pyelonephritis and hydronephrosis may need to be accepted (15).

A report from COG (16) looked at image-based feasibility of NSS for very low-risk unilateral WT. Pre-operative CT scans of a favorable sub-group (patient age younger than 2 years with unilateral stage I WT weighing <550 g with no positive lymph nodes) were reviewed by a COG renal tumor committee surgeon and a COG renal tumor committee radiologist. Together they discussed the feasibility of NSS in each patient. The criteria for feasibility were (I) the ability to perform the procedure *in situ*, (II) the absence of tumor involving and/or directly abutting the renal hilar vessels, and (III) the ability to obtain a margin greater than 1 cm while preserving at least a third of the renal unit. This report found that only 8% of these favorable candidates were deemed suitable for NSS based on imaging analysis. By comparing pre-operative radiological prediction of NSS feasibility with pathological findings on resected specimens, Moorman-Voestermans and colleagues predict that pre-operative imagining studies may predict the feasibility of NSS with 80% sensitivity, 97% specificity, and 87% accuracy (17). In the adult population, scoring systems such as the RENAL nephrometry scoring system help to delineate the complexity of tumors and provide a guide regarding feasibility of NSS. However, application of this scoring system to the pediatric population found that most tumors in young children are highly complex and although this system allowed the identification of less complex tumors amenable to NSS in older children and adolescents, its utility was limited in young children with WT (18).

Cost *et al.* (12) describe the 'ideal candidate' for NSS as a tumor that is (I) a unifocal mass located outside of the renal hilum (and, therefore, polar and amenable to NSS) sparing a third or more of normal kidney, (II) of favorable histology, (III) shows no features of renal sinus or segmental vascular invasion, (VI) associated with no metastatic LNs, intraoperative tumor spill or gross regional disease at surgery, and (V) has a distinct interface between tumor and renal parenchyma. This group performed a post-hoc histological review of 78 RN specimens from their institution and found that 24.4% of patients met all 5 of the above criteria. This information highlights the potential underutilization of NSS in selected cases, even without the use of neoadjuvant chemotherapy.

Criteria for NSS, the surgical complications and oncologic outcomes of various clinical series, as well as proposed criteria for determining NSS feasibility are compared in *Figure 1*. Consultation and case review with a surgeon with significant experience with NSS may be beneficial to guide decision-making in children with BWT (21).

Technical considerations

The most commonly performed NSS is partial nephrectomy (PN) (3,8), as this allows for resection of the tumor with a rim of normal tissue. Other options include wedge resection and enucleation (8) (see *Figure 2*). The traditional approach to PN is through a trans-abdominal incision (3,22), although a retroperitoneal approach has been described (23). The kidney should be fully mobilized on the vascular and ureteric pedicle, and then walled off from the peritoneum using large abdominal swabs (3) or by surrounding the kidney with sterile plastic (22). Vessel loops should be placed around the vascular pedicle to facilitate control in case of bleeding, even if the surgeon does not intend to clamp the vessels. A bloodless field is essential to safe surgery, and this can be achieved by simply placing bulldog or other vascular clamps on the hilar vessels. Many surgeons avoid clamping off the vascular pedicle entirely however, opting instead to occlude the pedicle with a finger (22), or to digitally compress the renal parenchyma proximal to the tumor (3). The administration of intravenous Mannitol 5–7 minutes prior to vascular occlusion may prevent ischemic renal damage by decreasing intracellular edema and intrarenal resistance (3,24). Simple clamping of the vessels allows the surgeon around 20–30 minutes of warm ischemic time in which to perform the resection, but cooling the kidney either with either surface ice slush or with continuous *in situ* cold perfusion allows for a longer time to work. *Ex vivo* 'back-bench' tumor resection with auto-transplantation is seldom used (3).

The procedure can also be performed with laparoscopic assistance, wherein kidney exposure and control of the renal hilum with vessel loops is obtained laparoscopically, before deciding on an optimal skin incision site, which can then also be smaller than for a purely open procedure. Lopes *et al.* describe a series of 6 patients operated using this technique: in this series, it was never necessary to occlude the renal pedicle, and so there was no ischemia during the procedures (25).

Gerota's fascia and the perirenal fat overlying the tumor should be left in situ, to be removed along with the tumor.

Intra-operative ultrasound (IOUS) can be used to delineate tumor margins, although a positive margin rate of up to 22.5% has been described, despite its use (24). Once the area for PN is identified, the parenchyma is incised sharply with a blade, or scored with diathermy, leaving a 0.5–1 cm margin of normal parenchyma. The PN is then performed, coagulating smaller vessels and ligating larger ones (3,22). The collecting system should be closed with absorbable sutures. A double-J stent can be placed to assist with drainage and potentially decrease the likelihood of urine leak (22). The renal defect can be covered with perirenal fat, omentum, or oxidized cellulose (3).

Lymph nodes should be sampled thoroughly. This remains a critical technical point. Not performing lymph node sampling is one of the most common omissions during radical nephrectomy, with important therapeutic consequences. Its value is equally present in NSS.

Outcomes

Data on NSS in children with WT remains scarce, and most studies are retrospective cohorts and case series (22). From the SIOP WT 2001 study, 91/2,800 (3%) of patients underwent NSS for unilateral WT. Compared to the patients in the same study who underwent RN, there was no difference in the reported number of tumor capsule ruptures or lymph node ruptures. In the subgroup amongst these patients with a Stage III tumor, 87% of these were Stage III due to a positive margin. A quarter of these patients underwent conversion to RN, and another quarter had radiotherapy only. The 5-year OS and EFS were 100% and 94.9% respectively, which was not statistically different from the survival outcomes in the RN group when looking at the localized disease population only. There was a trend towards a higher number of surgical complications in the NSS group, but this did not achieve statistical significance (8).

A recent systematic review of NSS for WT found that most current studies seem to show similar rates of tumor rupture, recurrence, ESRD and survival between patients undergoing NSS and RN, but notes that differences in heterogeneity and cohort reporting makes meaningful and pooled comparisons of NSS and RN nearly impossible (26). Cost *et al.* identified 82 patients from the literature who underwent NSS for non-syndromic unilateral WT and compared them to a cohort from their own institution who underwent RN, and found that once stage was controlled for, there was no statistical difference in oncological outcomes (12).

Clinical series					
Authors	**Sample**	**Criteria for NSS**	**NSS performed %**	**Surgical complications**	**Oncological outcomes**
Horwitz *et al.*, 1996 (19)	98 patients; Fourth NWTS; synchronous bilateral WT	Synchronous bilateral WT	100%	Intestinal obstruction (7/94); urine leak (4/98)	Local recurrence: 8%; 4-year survival: 81.7%
Moorman-Voestermans *et al.*, 1998 (17)	90 patients; single centre; consecutive confirmed WT cases	Tumour in functional kidney; confined to single pole; occupies <1/3 of kidney; no vascular or collecting system invasion; clear margins visible between tumour and kidney or surrounding tissues; tumour resection would leave at least 60% of residual kidney *in situ*	7/90 (7.8%)	Not recorded	Local recurrence: Nil; 5-year survival: 5/7
Davidoff *et al.*, 2008 (15)	12 patients; Single centre; Synchronous BWT; Pre-operative chemotherapy given in all cases	Any patient with synchronous BWT unless NSS clearly contra-indicated (examples: renal failure with bilateral, diffuse anaplastic WT; patient requiring anticoagulation for CPB for resection of atrial thrombus)	10/12 (83%)	Persistent urine leak (3/10); urinoma (1/10); pyelonephritis (1/10); adhesive SBO (2/10); UPJO (1/10)	Residual tumour on follow-up imaging: 2/10; local recurrence: 2/10; OS (3.9 years): 83%
Cost *et al.*, 2012 (20)	Eighty-two patients; published cases of PN for UWT identified through literature search	Varied between publications	100%	Not recorded	Local recurrence: 3/83; systemic recurrence: 3/83; local-systemic combined recurrence: 3/83; OS (4 years) 95.1%
Retrospective case reviews					
Authors	**Sample**	**Agreed criteria for NSS**			**Eligible cases**
Cost *et al.*, 2012 (12)	Seventy-eight patients; retrospective specimen review; single centre; all patients undergoing pre-chemotherapy and RN for UWT	(I) Unifocal polar mass, sparing at least 1/3 of kidney; (II) Favourable histology; (III) Absent renal sinus or segmental vascular invasion; (IV) No metastatic LNs, intra-operative tumour spill, or gross regional disease; (V) Distinct interface between tumour and renal parenchyma			24.40%
Ferrer *et al.*, 2013 (16)	60 patients; enrolled in COG study AREN0532; <2 years old; favourable histology; tumor weight <550 g; negative lymph nodes	(I) Procedure could be performed *in situ*; (II) Absence of tumor involving/directly abutting hilar vessels; (III) Able to obtain tumour margin of at least 1 cm; (VI) At least 1/3 of renal unit can be preserved			5/60 (8%)

Figure 1 Inclusion criteria, surgical complications and outcomes of NSS (12,15-17,19,20). NSS, nephron sparing surgery.

Minimally invasive surgery

Advances in technology and equipment have led to a drastic increase in the use of minimally invasive surgical (MIS) techniques across all surgical specialties, but the use of MIS in the treatment of WT is still an area of controversy and more clinical trials are needed to settle the question of its safety. Laparoscopic and robotic urologic surgery is often the technique of choice for radical nephrectomy in the adult population. Although lagging initially, the adoption of MIS in the pediatric urologic population has become increasingly common. Use of MIS for oncologic resection, however, remains low compared to non-oncologic indications. During a recent survey, only 13% of pediatric surgeons favored MIS approaches for WT, in contrast to 88% for appendectomy and 90% for fundoplication (27). Data from the National Cancer Database finds that 5% of surgeries for WT are performed using MIS (28).

Historically, recommendations for WT management called for open surgical excision only. Arguments against

MIS include the skill required for laparoscopy, decreased lymph node sampling (which affects disease staging), a perceived higher chance of tumor spillage or incomplete resection (which affects OS), and the need for laparotomy to remove the mass regardless of whether the procedure is started in an open or laparoscopic fashion.

Currently, there are no gold standard recommendations regarding MIS in WT management, and radical nephrectomy via a trans-abdominal or thoraco-abdominal incision is still recommended by many authors (21). The SIOP UMRELLA protocol does not advocate for MIS given the lack of safety reporting, however, it does provide some guidance. The protocol states that MIS for WT management is permissible for small central tumors with a rim of non-malignant renal tissue, where adequate lymph node sampling is possible (29). Contraindications include tumor infiltration of extrarenal structures, tumor extension beyond the border of the spinal column, thrombus in the renal vein or vena cava, tumor without any response to chemotherapy, and lack of experience in laparoscopic surgery, or those patients in
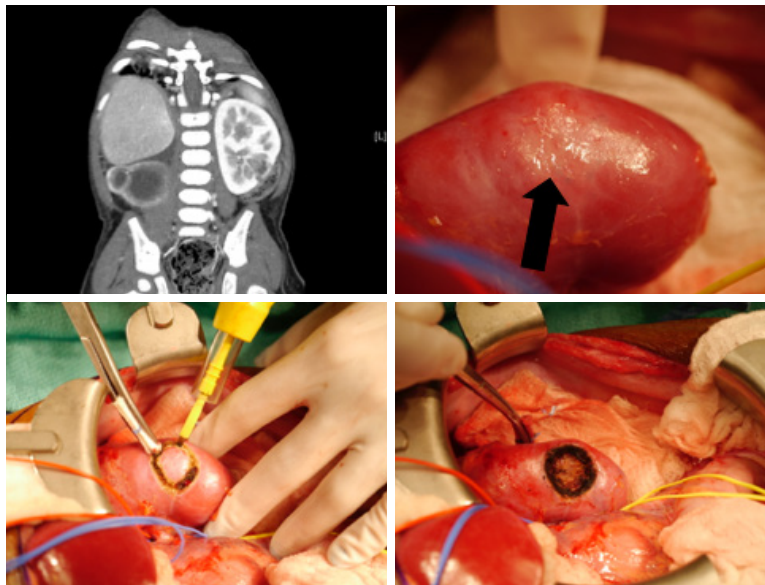
Figure 2 Bilateral Wilms tumors, with small inferior pole lesion in left kidney (indicated by black arrow). Lesion is resected after hilar control using monopolar cautery, with rim of normal renal tissue.

whom NSS cannot be performed (29). Alternative guidelines have proposed that MIS tumor resection should only be performed following induction chemotherapy and should be followed by adjuvant therapy (30). Clearly, experience plays a role. For example, Burnand *et al.* have reported that in experienced hands, tumors crossing the ipsilateral spinous processes may be resected safely with MIS, and adequate lymph node dissection achieved (31).

Patient selection

The most important factor agreed on by all surgeons is the importance of appropriate patient selection for MIS. Amenable patients are typically those presenting with small tumors or small tumor burden following chemotherapy, although Duarte *et al.* suggest that the absolute tumour size is of less importance than the dimensions of the tumor relative to the patient morphometrics (32). When comparing open *vs.* laparoscopic nephrectomy for WT, Romao *et al.* reported a significant difference in tumor size between the two techniques (33). Assessment of tumor size and extension is critical because it correlates with intraoperative tumor spillage (34). That said, tumors as large as 12 cm have been excised laparoscopically (32). Tumors that do not cross the ipsilateral vertebral border, and which allow for adequate manipulation for nodal dissection may be considered favorable for MIS (34,35). Preoperative imaging

review is also critical to determine port placement, which will dictate positioning for both renal resection and lymph node sampling.

Benefits

The benefits of MIS in general are well documented. Optimal visualization allows for precise dissection. Smaller incisions and lower operative trauma allow for less pain, earlier post-operative feeding, shorter postoperative hospital stays and quicker return to regular activity (30). In patients with WT, laparoscopic surgery has been shown to have shorter hospital stay and less narcotic use compared to open techniques. The small Pfannenstiel incision generally employed during laparoscopic WT surgery has advantages over a large subcostal or transverse laparotomy incision in that it is cosmetically more acceptable and allows for more rapid post-operative recovery. Studies have shown that overall oncologic outcomes are similar (28), and risk of local recurrence following laparoscopic nephrectomy is as low as 3.8% (36), although this may be biased by the fact that patients undergoing MIS have tumors of lower stages.

Potential pitfalls

As stated previously, complete tumor resection without tumor spillage reduces the risk of local and abdominal

recurrence. Surgeons without extensive experience with laparoscopy may be hesitant to attempt MIS for the treatment of WT due to the concern for tumor rupture in these patients. A small working space makes exploration of the renal pedicle difficult, particularly in patients with large masses or those that cross the ipsilateral spinous process. Thoroughness of lymph node sampling is another key prognostic factor in patients with WT. In comparison to open nephrectomy, laparoscopic nephrectomy had a lower yield of lymph nodes (median 2 *vs.* 5) (33) in multiple studies. Retrospective review of the SIOP 2001 cohort demonstrated only 63% of MIS cases for WT had any lymph node sampling at all (37).

Lymph node sampling

Lymph node sampling at the time of tumor resection is critically important (21). Lymph node stage affects pathologic staging and directs adjuvant treatment. Due
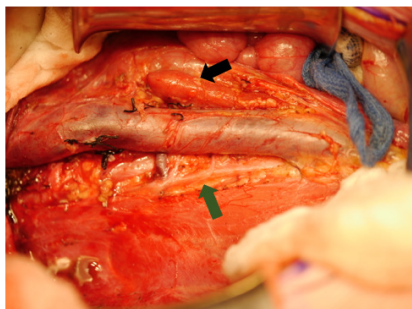
Figure 3 Inferior vena cava (IVC), which has been cleared of lymph nodes to its right (indicated by green arrow: note the visible sympathetic chain and lumbar vessels). The black arrow indicates a lymph node to the left of the IVC which was also resected.

to the known discrepancy between clinical assessment and histologic findings, surgical harvest is essential, and sampling of ipsilateral nodes is the current standard of care. Presence of node positive disease within the abdomen advances pathologic staging to 3, while node positive extra-abdominal findings upgrade to stage 4. Studies have shown that up to 41% of patients with stage 3 reach that diagnosis based on pathological lymph node positivity alone (38). LN density, which is the proportion of positive LNs relative to the total number of LNs evaluated, can also be used to predict OS, with a LN density of ≤0.38 being a positive predictor for 5-year survival (39). *Figure 3* demonstrates the surgical bed around the IVC which in the process of being cleared of lymph nodes.

The majority of children with WT undergo cross sectional imaging, most often with CT scan. The reported correlation of CT staging and pathologic staging varies from 38% to 75%. Recent arguments have centered around the lack of size criteria for nodal positivity in children. In adults, a lymph node of >1 cm on CT scan is interpreted as abnormally enlarged. Lubahn *et al.* have established that in children with WT, a diameter of 7mm or more is associated with node positivity with a negative predictive value of 89.0%, a sensitivity of 70.0% and a specificity of 57.1% (40). In those patients enrolled in the SIOP trials, it has been demonstrated that radiologic changes in tumor volume following preoperative chemotherapy do not indicate lymph node status (41).

One of the most common errors during surgery is the omission of lymph node sampling. Examination of the US National Cancer Database demonstrated that 42% of patients did not have adequate nodal assessment, which is lower than NWTS/COG and SIOP studies which quoted sampling rates of 9% and 33% respectively (42). Failure to perform sampling may lead to understaging, an increased
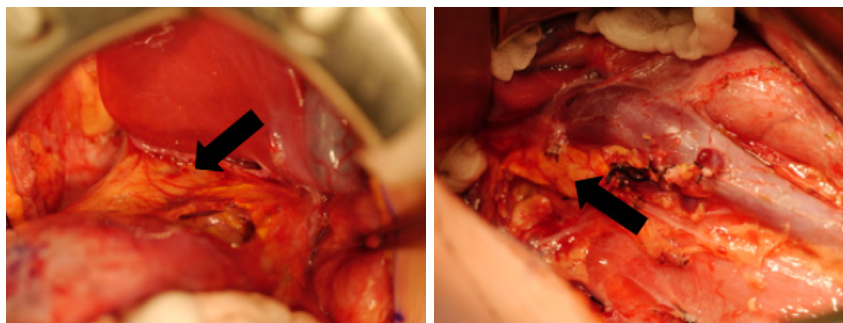
Figure 4 Black arrow indicates adrenal gland, which was separated from tumor and left *in situ* in this case.

risk of recurrence and poor outcome (43). Lack of lymph node biopsy is also an independent indicator of lower OS (44). Following operative resection of the tumor, ipsilateral lymph node sampling is required. Nodal tissue from the renal hilum and the great vessels should be harvested. A key operative principal in these patients is adequacy of nodal dissection. Mathematic models have demonstrated that when histology is favorable, the adequate number of nodes required to reduce the likelihood that a positive lymph node is missed to below 10% is between 6 and 10. Up to 30% of patients may have occult lymph node involvement when comparing lymph node yields of 2 *vs.* 10 nodes (45). This is confirmed by NWTS, which demonstrated that patients with positive lymph nodes increased as the yield of lymph nodes sampled increased. This correlation showed a plateau in the LN positivity rate at about 28% at 7 or more nodes (43).

Pre-operative chemotherapy

The decision to administer pre-nephrectomy chemotherapy in patients who are candidates for upfront nephrectomy is usually dependent on institutional protocol preference. Typically, North American groups opt for upfront nephrectomy based on the NWTS/COG protocol, whereas European groups often elect to administer pre-nephrectomy chemotherapy in accordance with SIOP protocols. It is well recognized that in environments that are dissimilar to those encountered in North America and Europe, adapted treatment protocols are required in order to offer patients the best outcome possible with the available economic and health system resources (46).

The SIOP and COG protocols regarding the administration of pre-nephrectomy chemotherapy are both safe and result in similar OS. Pre-surgical chemotherapy reduces tumor volume rendering them less likely to rupture, making this an attractive option in cases of large, operatively challenging cases of WT, and in patients where NSS or MIS are a possibility. Pre-nephrectomy chemotherapy also reduces the risk of intra-operative hemorrhage and increases the proportion of patients with low-stage tumors. Because the SIOP strategy relies on a presumptive diagnosis of WT and histological confirmation is confirmed through biopsy only in 'atypical' presentations (47), the risks of pre-nephrectomy chemotherapy include the possibility of the administration of unnecessary chemotherapy in patients with benign disease, or the administration of the incorrect chemotherapy to a tumor that is in fact not

a WT. Furthermore, pre-nephrectomy chemotherapy administration may result in the loss of important staging information, with under-estimation of disease extent resulting in sub-optimal treatment (48).

As we learn more about tumor biology, the possibility of tailoring the surgical and chemotherapeutic approach to each patient's molecular characteristics may become more of a reality.

Contralateral exploration

With the availability of modern high-quality cross-sectional imaging, contralateral renal exploration for patients undergoing surgery for unilateral WT is largely unnecessary. Historically, contralateral exploration was recommended when excretory urography was the only pre-operative imaging modality. Now, with the advancement of CT scan and MRI, lesions measuring millimeters can be detected pre-operatively. Several studies have demonstrated high sensitivity and specificity (close to 100%) with these modalities, with no evidence of missed disease during contralateral exploration (49). Ritchey *et al.* found that routine contralateral exploration may yield a small number of occult lesions not identified on pre-operative imaging, but that omission of routine contralateral exploration is unlikely to affect the outcome of any children with newly diagnosed WT, as long as they underwent CT or MRI scan prior to surgery (50).

Adrenal preservation

Little guidance is given regarding ipsilateral adrenalectomy in either the SIOP or the COG protocols. It is described historically as a standard step in RN for renal cell carcinoma (RCC) and is supported by the finding of malignant involvement of the adrenal gland in both surgical and pathological specimens. In a retrospective chart review of two groups of WT patients—one group who underwent adrenalectomy and one group where the adrenal gland was preserved—Moore *et al.* (51) found that the adrenal gland showed malignant invasion in only 1/58 patients, and peri-adrenal fat involvement was noted in 3/58 patients. There was no statistically significant difference in retroperitoneal recurrence between the groups. Subsequently, these findings were confirmed by COG on review of the NWTS-4 and -5 cohorts (52). Where surgically feasible, it seems that adrenalectomy can be avoided during RN (21,52). *Figure 4* demonstrates and adrenal gland left *in situ* after

radical nephrectomy for WT.

Pulmonary metastasectomy

Approximately 10% of patients with WT present with pulmonary metastases (PM), but they still have good OS rates (53). Traditionally, lung nodules are treated with whole-lung radiation with good disease outcomes, but this is associated with a significant increase in the incidence of pulmonary disease in the long-term (54).

Historically, PM were diagnosed and followed on chest X-ray (CXR), but the introduction of CT scan allowed the diagnosis of lesions that were less 1cm in diameter, and which could not be seen on CXR (55). The new appreciation of these undiagnosed lesions brought with it the question of how these lesions should be addressed. As many as 26% of these lesions might prove to be benign on biopsy, and might not require treatment (56), but data also demonstrates that children with CT-only lesions are at higher risk for pulmonary relapse if these lesions are not treated (57). A report from COG on the NWTS-4 and -5 found that these patients had improved 5-year EFS if they received 3 chemotherapeutic drugs rather than 2, although the OS between the 3- and 2-drug subsets was the same. In these patients with CT-only nodules, there was no difference in EFS or OS whether or not they had lung radiation (55).

The SIOP 93-01 protocol allows for pulmonary metastasectomy in patients who do not have complete resolution (CR) of pulmonary nodules after initial chemotherapy. Patients with known PM undergo CT scan at the time of nephrectomy, and if there is CR they continue the same chemotherapy regimen for 27 weeks. If there are still residual nodules, these are resected if feasible, and the same chemotherapy regimen is given. Patients where PM are incompletely resected or resection is not feasible are given a further high-risk chemotherapy regimen. If CR is still not achieved after this, either with chemotherapy or with metastasectomy, pulmonary radiotherapy is applied to both lungs (58). In a study of 234 patients with PM, Verschuur and colleagues found that following this protocol, radiotherapy could be omitted for the majority of patients and that outcomes were still relatively good. As such, pulmonary metastasectomy is accepted as a reasonable option in patients whose PM do not clear with chemotherapy alone, as it may reduce the radiation burden in this group.

Conclusions

WT is a common pediatric tumor with generally excellent outcomes. International collaboration on the COG and SIOP databases and studies provides clinicians with a vast body of evidence-based data with which to manage these patients. Ongoing study allows for ongoing adaptations to management, with the goal of improving survival further whilst at the same time reducing treatment-associated morbidity and mortality.

In terms of surgical options, NSS in a select group of patients may help to preserve functional renal units and long-term renal function, without compromising OS and EFS. Minimally invasive surgical techniques are safe in experienced hands, and in appropriate patients. Thorough lymph node sampling is essential for disease staging and to direct adjuvant therapy. Contralateral exploration is becoming far less common in the era of highly sensitive and specific cross-sectional imaging, and data shows it is safe to preserve the ipsilateral adrenal gland where technically feasible. Pulmonary metastasectomy may provide good survival outcomes whilst obviating the need for whole-lung radiotherapy in patients with nodules that do not clear with chemotherapy.

Acknowledgments

Footnote

or integrity or any part of the work are appropriately investigated and resolved.

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