

Intra-operative cell salvage in urological surgery; a systematic review and meta-analysis of comparative studies

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NK created the report concept and wrote the initial manuscript. MOC created the statistical analyses. All authors refined the final manuscript, and agree to be accountable for all aspects of the work.

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ABSTRACT

Objective

To systematically evaluate the safety and efficacy of intra-operative cell salvage (ICS) in urology.

Methods

A search of Medline, Embase and Cochrane Library to August 2017 was performed using methods pre-published on PROSPERO. Reporting followed the Preferred Reporting Items for Systematic Review and Meta-analysis guidelines. Eligible titles were comparative studies published in English utilising ICS in urology. Primary outcomes were allogeneic transfusion rates (ATR) and tumour recurrence. Secondary outcomes were complications and cost.

Results

Fourteen observational studies were identified, totaling 4,536 patients. ICS was compared to no blood conservation technique (seven studies), pre-operative autologous donation (PAD) (five) or both (two). Cohorts underwent open

prostatectomy (eleven studies), open cystectomy (two) or open partial nephrectomy (one). Meta-analysis was possible only for ATR within prostatectomy studies. In this setting, ICS reduced ATR compared with no blood conservation technique (OR 0.34, 95% CI 0.15-0.76) but not PAD (OR 0.76, 95% CI 0.39-1.31). In the non-prostatectomy setting, ATR amongst ICS patients was significantly higher or similar in one and two studies respectively.

Tumour recurrence was found to be significantly less common (two studies), similar (eight) or not measured (four). All six studies reporting complications found no difference for ICS cohorts. Regarding cost, one study from 1995 found ICS more expensive than PAD, while two more recent studies found ICS cheaper than no blood conservation technique. Due to inter-study heterogeneity, meta-analyses were not possible for recurrence, complications or cost.

Conclusion

Low level evidence exists that compared with other blood conservation techniques, ICS reduces ATR and cost while not affecting complications. It does not appear to increase tumour recurrence post-prostatectomy, although follow-up durations are short. Small size and short follow-up negate conclusions on recurrence following nephrectomy or cystectomy. Randomised trials with long term follow-up evaluating ICS in urology are required.

Keywords

intra-operative cell salvage, cell salvage, autologous blood, autotransfusion, urology, prostatectomy.

MANUSCRIPT

1. Introduction

Intra-operative blood loss remains a challenge in urology. Over time, allogeneic transfusion rates (ATR) have progressively fallen for many urological procedures, aided by successive waves of new technology such as minimally invasive surgery and novel operative energy sources (1, 2). However, even in high volume centers, ATR remain high for the hallmark open oncological procedures of radical nephrectomy [$<45\%$ (3)], cystectomy [$<60\%$ (4)] and prostatectomy [$<9\%$ (5)].

The introduction of well-resourced blood banks has made allogeneic blood transfusion safer. Nevertheless, this practice carries key challenges of transfusion-transmitted infections (TTIs), transfusion reactions and potentially poorer oncological outcomes (6-8). Additional problems include supply and cost. Blood bank shortages are well reported (9). A single red blood cell (RBC) unit costs approximately USD \$1000 in Australia and the United States of America (USA) and USD \$600 in Western Europe (10, 11). These difficulties are dramatically increased in the developing world (12). Lastly, as with other malignancies, recent meta-analyses for patients undergoing radical retropubic prostatectomy (RRP), radical nephrectomy (RN) or radical cystectomy (RC) have found that allogeneic blood transfusion is associated with worse oncological outcomes (13, 14). Mechanisms remains poorly understood, and may relate to transfusion-related immunomodulation (TRIM) (15).

Surgeons have a range of peri-operative blood conservation techniques at their disposal. These include pre-operative erythropoietin or iron supplementation, pre-operative autologous donation (PAD), acute normovolaemic hemodilution (ANH), restrictive transfusion thresholds and intra-operative cell salvage (ICS). However, each has limitations. Supplements are only applicable for patients with anaemia or iron-deficiency, require multiple healthcare episodes for testing, administration and re-testing and are ambiguously efficacious (16). Stimulated by the emergence of TTIs, particularly human immunodeficiency virus (HIV), PAD was initially deemed the safest blood conservation technique (17). However

it similarly requires additional patient visits, approximately 50% of pre-donated units are discarded, is not cost effective and is now rarely used (17, 18). ANH consists of intra-operation collection of patient blood, replacement with colloid or crystalloid to allow haemorrhage of dilute blood, then re-infusion of the collected blood. While cost effective, it may cause hypotension and is unsuitable for patients with low haematocrit (17, 18). Restrictive thresholds have become commonplace, with clear benefit (19). However, they are inappropriate for patients with symptomatic or significant haemorrhage.

ICS represents the safe reinfusion of lost blood. Blood spilled in the surgical field is aspirated with a sterile dual-lumen sucker, with either heparinised saline or citrate added to the second lumen to prevent coagulation. Blood is collected in a reservoir. When desired, these losses are washed with saline and centrifuged to obtain a concentrate with haematocrit of 50-70%. This product is then re-infused, often after passing through a leucocyte depletion filter (LDF), to remove nucleated cells such as bacteria and tumour cells (20).

This ICS system elegantly sidesteps many concerns of other blood conservation techniques. It is cost effective, the risk of horizontal transmission of infection is almost eliminated and supply closely matches demand. ICS has enjoyed enthusiastic uptake and positive results in cardiac, vascular and orthopaedic surgery, where blood loss is often substantial (21). However, uptake in urology has been slow, due to concerns of cost, unclear benefit and potential reinfusion of malignant cells (22-24).

To date, no systematic review exists regarding ICS efficacy in urology. Therefore, this review aims to summarise current data regarding the impact of ICS in urological procedures on ATR, oncological outcomes, complications and cost. We hypothesise that ICS will reduce ATR and be equivalent or superior in other measures.

2. Methods

2.1 Search strategy

A systematic search of Cochrane Central Register of Controlled Trials (CENTRAL), Embase and Medline was conducted in August 2017. Grey literature was also searched. The complete free-text search terms, search strategy and list of retrieved full text articles are attached (*Appendices 1 and 2*). The only limit applied for searches was a publication date prior to 1 August 2017.

2.2 Inclusion criteria

Inclusion criteria were agreed upon by all authors. Our method for identifying and evaluating data complied with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) criteria (25) (*Figure 1*). This included pre-publication of our intended analysis on PROSPERO (CRD42017071627). Identified studies were screened by title and abstract, followed by full text review. Articles then progressed to data extraction, including review of references. Two independent authors performed study screening and data extraction, using a pre-defined form (*Appendix 3*). Data extraction was performed twice, to confirm accuracy. The final list of included articles was determined by compliance with the inclusion criteria and with the consensus of all authors.

2.3 Study eligibility

Study eligibility was determined utilising the patient population, intervention, comparator, outcome and study method (25). Eligible studies assessed patients undergoing urological surgery (P), had a cohort treated with ICS (I), a comparator cohort without (C), and reported outcomes on any of ATR, tumour recurrence, complications or cost (O). Eligible studies were original, published in English, comparative in nature and not a case series or case report (S). If randomised controlled trials (RCT) were found and adequate reason existed to include non-randomised studies (NRSs), they were to be presented separately. If multiple studies with overlapping samples met the inclusion criteria, these were included with their commonality made clear.

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2.4 *Intended analyses*

Qualitative summary was intended for all data. Quantitative synthesis (meta-analyses) was planned if sufficient similar studies were available, performed as sub-groups by operation type.

Meta-analysis was performed in Review Manager Software version 5.3 (the Nordic Cochrane Centre, the Cochrane Collaboration, Copenhagen, Denmark). For each study included in the meta-analysis, the number of cases and controls, and outcomes per group were extracted. Fixed effects analysis was used throughout. Forest plots were used to assess publication bias for each meta-analysis.

2.5 *Bias*

The authors did not expect to identify any RCTs. As such, risk of bias was assessed with the Newcastle-Ottawa Scale, in accordance with the Cochrane Handbook (26, 27). Two reviewers independently assessed each study according to pre-defined guidelines (**Appendix 4**). These were informed by the typical demographics and recurrence time frames of patients undergoing RRP (28, 29), RC (30) and PN (31). Disagreements were resolved by consensus. Studies were not excluded on the basis of risk of bias. Publication bias was assessed with funnel plots.

3. **Results**

Our search identified 170 manuscripts (01 August 2017). Elimination occurred due to irrelevance (51 titles), lack of comparator group (23 titles), ICS being discussed but not performed (16 titles), not published in English (9 titles) and ICS product not reinfused (4 titles). 14 original articles were selected for inclusion (**Fig. 1** and **Table 1**). All were observational studies, representing low level evidence. Eligible publications assessed patients undergoing open RRP

(eleven studies (22, 32-41)), open RC (two studies (17, 42)) and open partial nephrectomy (PN, one study (43)). There were no studies of ICS during urological laparoscopic or robot-assisted procedures, nor for other major urological procedures associated with high peri-operative transfusion rates, such as retro-peritoneal lymph node dissection.

ICS was compared to PAD (22, 32-35, 38, 41), no ICS (17, 36, 37, 39, 40, 42, 43) or no transfusion (32, 34). Some studies had more than one comparator group. The primary outcomes were ATR (twelve studies) and cancer recurrence (ten studies), with secondary outcomes of complications (four studies) and cost (three studies). Of note, overlapping samples were found, with groups of two (38, 41) and three (34, 36, 40) studies representing enlarging RRP sets at the same institutions. These were included and clearly highlighted.

3.1 Allogeneic transfusion rates

Twelve studies reported ATR. Compared with other blood conservation techniques, ATR in cohorts receiving ICS were decreased (two studies (33, 39)), unchanged (nine studies (17, 22, 32-36, 38, 41, 43)), or increased (one study (42)).

Examining by procedure, the sole PN study and one of the RC studies reported equivalent ATR in the ICS and control groups (17, 43), while the remaining RC study reporting significantly higher ATR in the ICS cohort (42). In these three papers, the control group received no other blood conservation technique.

Studies differed substantially in their transfusion thresholds. The most common approach was holistic, with a joint surgeon-anaesthetist decision to transfuse, taking into account pre-operative haemoglobin, patient comorbidities, estimated blood loss and vital signs (17, 32, 36, 39-42). Some used strict criteria of estimated blood loss or haemoglobin/ haematocrit level (22, 33-35). Some studies had unclear or unstated allogeneic transfusion triggers (38, 41, 43).

3.1.1 Subgroup – radical retropubic prostatectomy; ICS versus no blood conservation technique

In four studies of patients undergoing RRP, ATR were compared between groups of ICS and no blood conservation technique (32, 34, 36, 39). These data were suitable for meta-analysis, which found a significantly reduced odds ratio (OR) for ATR amongst ICS patients of 0.34 (95% CI 0.15–0.76) (**Figure 2**).

3.1.2 Subgroup – radical retropubic prostatectomy; ICS versus pre-operative autologous donation

Seven studies regarding RRP reported ATR in ICS and PAD groups (22, 32-35, 38, 41). Meta-analysis found a non-significant trend towards reduced ATR amongst ICS patients, with OR 0.71 (95% CI 0.39–1.31) (**Figure 2**).

3.2 Oncological outcomes

Ten studies reported oncological results (**Table 1** and **Appendix 5**). None found ICS to be associated with worse outcomes. Compared to controls, ICS patients had equivalent outcomes in studies of patients undergoing RRP (six studies) (33, 34, 36, 37, 39, 40), RC (one) (42) or PN (one) (43). The blood conservation techniques available to controls were either PAD in two RRP studies (33, 34) or no technique (36, 37, 39, 41-43). The remaining two titles reporting oncological data examined RRP patients and found that compared with PAD, the ICS cohort experienced superior outcomes (38, 41).

There was significant inter-study variation in follow-up, recurrence determination method and reported oncological outcomes. Follow-up for ICS cohorts ranged from 7 - 61 months (median 32 months). This short follow-up is a major limitation of the data. Assessment of tumour recurrence after RN and RC was quite uniform, utilising clinical and radiological assessment in all three studies. By contrast, recurrence after RRP was variously determined by biochemical recurrence (BCR) defined as serum prostate specific antigen >0.2ng/L (34, 37, 39-41), > 0.4ng/L (33, 36), by the prescription of adjuvant

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therapies (33, 37) or per hospital registry (38). Some studies used multiple definitions of recurrence.

Stated oncological outcomes included progression-free survival, disease-specific survival and biochemical recurrence. Only four papers reported a survival analysis (33, 36, 40, 42). These comprised papers on RRP, RC and PN, with comparators of PAD or no blood conservation technique. Given the variation in follow-up, methodology and reporting, meta-analysis was not possible.

Oncological results for RRP studies which stated raw biochemical recurrence figures are presented in a forest plot, with the pooled estimate suppressed, in keeping with the Cochrane Handbook's guidance for heterogenous studies (*Figure 2*) (26).

3.3 Safety

Complications were reported by studies relating to RRP (one study) (32), RC (two) (17, 42) and PN (one) (43). In all analyses, complications were not significantly different between groups. Chiusano *et al.*'s three-way comparison of ICS, PAD and no blood conservation technique found no adverse events in any group (32). In the setting of RC or PN, complication rates for groups receiving ICS or no blood conservation technique were 39.5% vs. 40.5% (42) and 21% vs. 17% (43) respectively. Lastly, Ubee *et al.* reported non-cancer-related post-cystectomy peri-operative mortality in both ICS (one death) and no blood conservation technique groups (two deaths) (17).

3.4 Cost

Only three studies we identified examined the cost of ICS in urological surgery. In 1995, Gilbert *et al.* found that in managing RRP at their institution, pre-donating four units of autologous blood would be more economical than ICS and achieve similarly ATR risk reduction (USD \$976 vs. \$1409 per patient) (22).

Contrastingly, studies in 2010-11 in the United Kingdom by Ubee *et al.* regarding RC (17) and RRP (39) found favourable cost-benefit results. Per patient costs for

ICS vs. no blood conservation technique were UKP £320 vs. £675 and £163 vs. £673 respectively.

3.5 *Assessment of bias*

The Newcastle-Ottawa Scale suggested that risk of bias was low or moderate for ten and four studies respectively (*Appendix 6*). Most studies did not report ethics approval, conflicts of interest nor funding (*Appendix 7*). Similarly, the majority of studies excluded some patients, although in all cases the reviewers' deemed the reasoning appropriate. Two studies reported losses to follow-up, both representing <20% of the patient cohort.

Reporting bias may be present. This is particularly noticeable regarding complications, with one study stating intervention and comparator group adverse outcomes to be the 'same' without providing further data (17), and another reporting only deaths (35).

Funnel plots for each sub-set of RRP studies did not suggest publication bias, albeit these analyses were limited by the small number of studies (*Figure 3*). Publication bias was not assessable for the non-prostatectomy studies (39, 42, 43).

3.6 *Discussion*

This review found low level evidence that ICS reduces ATR, most clearly when compared with no blood conservation technique for patients undergoing RRP. ICS appears safe, with no evidence of worse complications or recurrence. Data on cost was mixed, with newer studies suggesting cost savings with ICS.

These findings are in line with several non-urological studies. The impact of ICS on ATR was assessed by two meta-analyses and a Cochrane Review. These found that compared to no blood conservation technique, the relative risks of allogeneic transfusion for patients receiving ICS was significantly reduced at 0.59 (95% confidence interval [CI] 0.48–0.73) (18), 0.61 (95% CI 0.57–0.65) (44) and

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0.62 (95% CI 0.55–0.70) (21). In this systematic review, studies reported a wide range of ATRs, often quite above those found in contemporary series also utilising the open approach (3-5). This is important for two reasons. Firstly, the ATR heterogeneity influenced the meta-analyses, as ICS exerts most benefit when ATR is high. For example, in the quantitative analysis of RRP studies comparing ICS with no blood conservation technique (*Figure 2.A*), Ubee *et al.*'s control arm experienced an ATR of 72%, and so a large beneficial effect estimate was demonstrated when ICS was utilised (39). This study of 50 patients had far greater impact on the pooled estimate than Nieder *et al.*'s experience with >1,000 patients but a much lower ATR of <2% in both groups (36). Secondly, the high reported ATRs may poorly correspond with modern experiences. Minimally invasive surgery, either laparoscopic or robot-assisted, is increasingly becoming the norm during prostatectomy, nephrectomy and to a lesser extent cystectomy, and is associated with lower ATR. Transfusion rates will vary by procedure, surgical approach, patient population and surgeon, and the benefits of ICS will be reduced when ATR are lower. Hence, health providers must examine averaged peri-operative transfusion indices for each of their major procedures to decide whether to utilise ICS. If published criteria are not met, such as estimated blood loss >20% of total blood volume, transfusion required in >10% of patients or mean transfusion exceeds one unit (49), for that procedure health providers should consider selective rather than routine use of ICS.

The sole prior meta-analysis of cancer recurrence in ICS by Waters *et al.* assessed eleven cohort studies (45), including five urological studies included in this review (33, 34, 36-38). Accepting inter-study heterogeneity, they found the pooled OR of cancer recurrence was lower for ICS patients (OR=0.65; 95% CI 0.43-0.98). This is consistent with the findings of this review, with the ten studies reporting recurrence data all demonstrating equivalent or superior oncological outcomes for ICS patients. Eight of these studies concern prostatectomy. However, only one of these have follow-up greater than five years. Still greater uncertainty exists for recurrence following ICS use in nephrectomy or cystectomy. Only one paper exists for each, both with small samples and limited follow-up.

ICS appeared not to affect complication rate, a finding supported by numerous non-urological studies. Large audits of ICS representing 18,000-64,000 units of salvaged blood have reported complication rates of <0.027%, akin to one complication per 3,700 units reinfused (46, 47). Similarly, a meta-analysis and a Cochrane review both found that complications rates were similar between ICS and other blood conservation techniques (18, 21). A more recent meta-analysis of 47 RCTs found that compared to allogeneic transfusion, ICS reduced the risk of post-operative infection (RR=0.72; 95% CI 0.54 to 0.97), with the risk of other complications unchanged (44).

Cost benefit remains a source of controversy. Three urological studies were identified reporting cost data. The oldest found ICS more expensive than PAD (22), while two more recent studies found ICS more economical than allogeneic transfusion alone (17, 39). These latter results echo the sole meta-analysis of the economics of ICS, by Davies *et al.* (18), which did not include urological studies. A wide range of blood conservation techniques were assessed, including erythropoietin, PAD, ANH, restrictive transfusion thresholds, fibrin sealants and antifibrinolytic drugs. ICS was found to be more cost-effective than all blood conservation techniques except ANH. With the cost of allogeneic transfusion high and increasing (48, 49), the business case for ICS continues to strengthen. However, other non-urological Western studies have not found ICS economical (50) and experience in the developing world has at best demonstrated cost equivalence (50, 51). A new ICS machine costs up to UKP £4,200, with UKP £77 disposables per use (39). This may challenge under-resourced health systems, where one unit of screened donor blood commonly costs USD <\$50 (52). Given inter-site variation in costs, transfusion requirements per procedure and healthcare models, ICS will not deliver savings for all users.

This is the first systematic review or meta-analysis of ICS in urology, and represents the highest English-language evidence to date on the topic. Twenty years ago, Jacobi *et al.* published in German a RCT of 24 patients receiving RRP, with patients randomized to ICS or allogeneic transfusion (53). Tumour recurrence data was not reported. This remains the sole urological RCT on ICS. Three reviews have previously covered sections of the urological ICS literature, This article is protected by copyright. All rights reserved

but each has key weaknesses (45, 54, 55). Waters *et al.*'s include only five of the fourteen studies identified in this review, and does not separate studies by blood conservation technique during meta-analysis (45). Kumar *et al.* and Ferroni *et al.* include seven and nine eligible urological studies respectively (54, 55). However, meta-analyses were not performed, and Kumar *et al.* erroneously included one non-ICS study. However, these reviews' findings echo our own, with ICS appearing to reduce ATR and cost, with unaltered rates of recurrence and complications.

This review's strength is its robust methodology and comprehensive collation of relevant literature. Limitations include the lack of RCTs and the heterogeneous methods of included studies. Potential biases are likely to be greater for NRSs, so results should be interpreted with caution. Of particular concern is the potential for differences in the baseline characteristics of individuals in different groups (e.g. selection bias). This is the key difference between RCTs and NRSs, and may affect this review, despite most studies stating some degree of statistical similarity between groups. While publication bias did not appear present, reporting bias did, with selected outcome reporting. Lack of information regarding ethical approval, funding and conflicts of interest were also common.

4. Conclusion

Low level evidence indicates that ICS use during uro-oncological surgery reduces both ATR and cost, and does not affect post-prostatectomy recurrence nor complication rates. Few nephrectomy or cystectomy studies, all of small size and short follow-up, invalidate judgments on tumour recurrence following these procedures. Meta-analysis of the sub-group of RRP studies suggests that ICS reduces ATR compared with no blood conservation technique but not compared with PAD. A pre-existing meta-analysis of observational uro-oncological studies also found ICS did not impact recurrence rates (45). Prospective randomised controlled trials with long-term follow-up will enable greater certainty of the impact of ICS in urology.

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Author contributions

NK, MOC, JB and NL created the concept and wrote the initial manuscript. NK and DH acquired and analysed the data. MOC performed the statistical analyses. All authors refined the final manuscript, and agree to be accountable for all aspects of the work.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical standards including informed consent

This article does not contain any studies with human participants or animals performed by any of the authors.

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Figures titles and captions

Figure 1 - Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram

Figure 2 – A. and B. Meta-analysis of allogeneic transfusion rates amongst radical retropubic prostatectomy studies, comparing cohorts with intra-operative cell salvage versus no blood conservation technique (A) or pre-operative autologous donation (B).

C. Forest plot of oncological outcomes, with suppression of the pooled estimate.

Figure 3 – A and B. Funnel plot of allogeneic transfusion rates amongst radical retropubic prostatectomy studies, comparing cohorts with intra-operative cell salvage versus (A) no blood conservation technique and (B) pre-operative autologous donation.

Table titles and captions.

Table 1: Patient characteristics and outcomes of eligible studies.

Age, follow up and estimated blood loss data listed as means unless otherwise indicated. **Shaded cell:** ICS outcome significantly different to comparator.

Abbreviations listed alphabetically; **Comp:** comparator. **complxn:** complications. **EBL:** estimated blood loss. **HCS:** Haemonetics Cell Saver®. **ICS:** intra-operative cell salvage. **LDF:** leucocyte depletion filter. **mL:** millilitres. **mo:** months. **N:** number of patients. **PAD:** pre-operative autologous donation. **PN:** partial nephrectomy. **p.p.:** per patient. **Proc:** procedure. **pts:** patients. **RC:** radical cystectomy with ileal conduit; prostatectomy also performed in male patients. **recur:** recurrence. **RRP:** radical retropubic prostatectomy. **t/f:** transfusion. **yr:** years. **%:** percentage. **-:** not stated.

Super-script notations: **a:** ICS patients also had PAD. **b:** includes all 408 patients from 2003 Davis. **c:** patients are sub-sets from 2009 McIvor. **d:** includes all 408 patients from 2003 Davis, and all 1038 patients from 2005 Nieder. **e:** multiple comparator groups, listed respective to order given in Comparator column. **f:** median. **g:** raw patient numbers not stated. **h:** individual treatment arm follow up not given.

Table 1: Patient characteristics and outcomes of eligible studies.

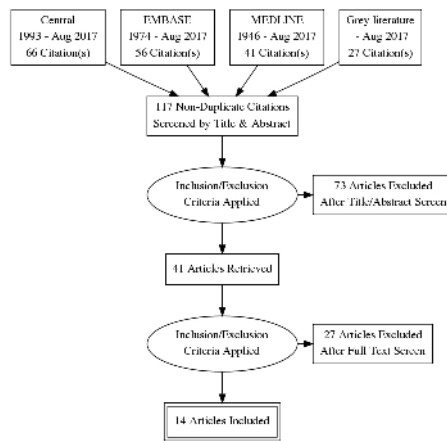
Study characteristics						Patient details								Primary outcomes				Secondary outcomes				
Year	Proc	Desi	Comp	ICS	Comp	ICS	LDf	Surg	ICS	Comp	ICS	Comp	ICS	Comp	ICS	Comp	ICS	Comp.	ICS	Comp	ICS	Comp
Author	gn			f/up	f/up	machine		eon	N	N	Age	.age	EBL	EBL	allogeneic	allogeneic	recur; N	recur; N	ICS	Comp	ICS	Comp
				(mo)	(mo)						(yr)	(yr)	(mL)	(mL)	t/f; N (%)	t/f; N (%)	(%)	(%)	N (%)	N (%)	cost	cost
																					p.p.	p.p.
1995	RRP	R, H	PAD ^a	-	-	HCS Plus	-	Sole	86	86	63	64	1377	1409	7 / 86 (8%)	7 / 86 (8%)	-	-	-	-	USD	USD
1996	RRP	R, C	PAD ^a or no ICS	0	0	HCS	-	-	14	8 + 5 ^e	61	67 + 67 ^c	2325	1650 + 2380 ^f	4/14 (29%)	5/8 (63%) + 5/5 (100%) ^f	-	-	0	0	-	-
2001	RRP	R, H	PAD	7	43	Seques tra 1000	Yes	Sole	62	101	62	63.3	1315	1410	2/62 (3%)	14/101 (14%)	3/62 (5%)	24% (24/101)	-	-	-	-
2003	RRP	R, C	PAD ^a or no t/f	40.2 ^h	40.2 ^h	HCS	No	Sole	87	264 + 57 ^e	-	-	-	-	0	0 + 0 ^f	13/87 (15%)	42/264 (16%) + 30/157 (19%) ^e	-	-	-	-
2004	RRP	P, C	PAD	40 ^h	40 ^h	HCS 5	Yes	Two	23	26	60	59	1134	892	5/23 (22%)	3/26 (12%)	-	-	-	-	-	-
2005	RRP	P, C	No ICS	43	46	Brat 2	No	-	48	64	61	61	1640	1210	-	-	9/44 (20%)	17/50 (34%)	-	-	-	-
2005 ^b	RRP	R, C	No ICS	40.3 ^f	44.4 ^f	n/s ^g	No	Sole	265	773	61.5	60.8	-	-	4/265 (2%)	5/773 (1%)	40/265 (15%)	139/773 (18%)	-	-	-	-
2007	RC	R, C	No ICS	19.1 ^f	20.7 ^f	n/s	No	Sole	65	313	67.8	69.2	862	537	24/65 (37%)	51/313 (16%)	27.8% ^h	27.0% ^h	39.5%	40.5%	-	-
2009	RRP	R, H	PAD	24.8	35.6	Brat 2	Yes	Sole	63	40	59.7	59.6	587	703	2/63 (3%)	0/40 (0%)	1/63 (2%)	5 (13%)	-	-	-	-
2010	RC	R, H	No ICS	23 ^f	21 ^f	Dideco Electra	Yes	-	15	15	65	64	1901	2270	9/15 (60%)	15/15 (100%)	-	-	1 death peri-op	2 deaths peri-op	UKP 320	UKP 675
2011	RRP	R, H	No	23	51	Dideco	Yes	Two	25	25	59.2	62.5	-	-	5/25	18/25	1 (4%)	4 (16%)	-	-	UKP	UKP

Ubee [39]			ICS			Electra									(20%)	(72%)					163	373
2012 ^c Raval [41]	RRP	R, H	PAD	61.1	65.0	Brat 2	Yes	Sole	42	32	64.2	66.1	-	-	1/42 (2%)	0/32 (0%)	4/42 (9.5%)	11/32 (34.4%)	-	-	-	-
2012 ^d Gorin [40]	RRP	R, C	No ICS	47 ^f	48 ^f	n/s ^g	No	Sole	395	1467	62 ^f	61 ^f	700 ^f	375 ^f	-	-	26.6% ^h	23.4% ^h	-	-	-	-
2015 Lyon [43]	PN	R, C	No ICS	21 ^f	25 ^f	HCS	n/s	Sole	33	36	64 ^f	61 ^f	600	200	7/33 (21%)	3/36 (8%)	0/33 (0%)	1/36 (2.8%)	same; 7/33 (21%)	6/36 (17%)	-	-

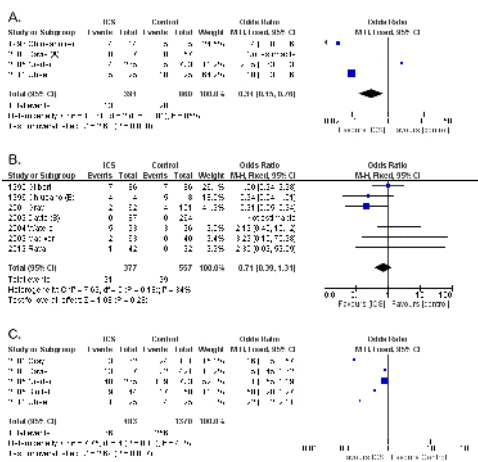
Age, follow up and estimated blood loss data listed as means unless otherwise indicated. **Shaded cell:** ICS outcome significantly different to comparator.

Abbreviations listed alphabetically; **C:** contemporary controls. **Comp:** comparator. **complxn:** complications. **EBL:** estimated blood loss. **H:** historical controls. **HCS:** Haemonetics Cell Saver®. **ICS:** intra-operative cell salvage. **LDF:** leucocyte depletion filter. **mL:** millilitres. **mo:** months. **N:** number of patients. **P:** prospective. **PAD:** pre-operative autologous donation. **PN:** partial nephrectomy. **p.p.:** per patient. **Proc:** procedure. **pts:** patients. **R:** retrospective. **RC:** radical cystectomy with ileal conduit; prostatectomy also performed in male patients. **recur:** recurrence. **RRP:** radical retropubic prostatectomy. **t/f:** transfusion. **UKP:** United Kingdom pounds. **USD:** United States dollars. **yr:** years. **%:** percentage. **-:** not stated.

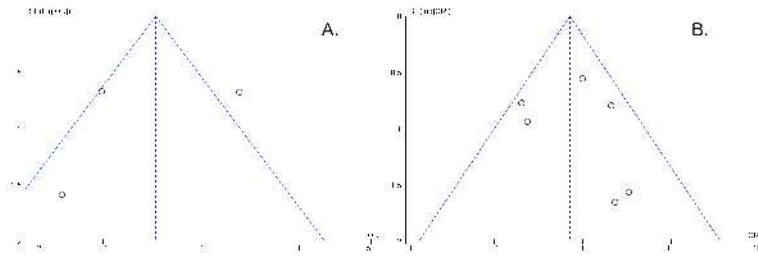
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