RESEARCH ARTICLE

A Comparison of Technique Modifications in Laparoscopic Donor Nephrectomy: A Systematic Review and Meta-Analysis

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Abstract

Objective
To compare the effectiveness of different technique modifications in laparoscopic donor nephrectomy.

Design
Systematic review and meta-analyses.

Data Sources
Searches of PubMed, EMBASE, Web of Science and Central from January 1st 1997 until April 1st 2014.

Study Design
All cohort studies and randomized clinical trials comparing fully laparoscopic donor nephrectomy with modifications of the standard technique including hand-assisted, retroperitoneoscopic and single port techniques, were included.

Data-Extraction and Analysis
The primary outcome measure was the number of complications. Secondary outcome measures included: conversion to open surgery, first warm ischemia time, estimated blood loss, graft function, operation time and length of hospital stay. Each technique modification was compared with standard laparoscopic donor nephrectomy. Data was pooled with a random effects meta-analysis using odds ratios, weighted mean differences and their corresponding 95% confidence intervals. To assess heterogeneity, the I² statistic was used. First, randomized clinical trials and cohort studies were analyzed separately, when data was comparable, pooled analysis were performed.
Results
31 studies comparing laparoscopic donor nephrectomy with other technique modifications were identified, including 5 randomized clinical trials and 26 cohort studies. Since data of randomized clinical trials and cohort studies were comparable, these data were pooled. There were significantly less complications in the retroperitoneoscopic group as compared to transperitoneal group (OR 0.52, 95%CI 0.33–0.83, I² = 0%). Hand-assisted techniques showed shorter first warm ischemia and operation times.

Conclusions
Hand-assistance reduces the operation and first warm ischemia times and may improve safety for surgeons with less experience in laparoscopic donor nephrectomy. The retroperitoneoscopic approach was significantly associated with less complications. However, given the, in general, poor to intermediate quality and considerable heterogeneity in the included studies, further high-quality studies are required.

Trial Registration
The review protocol was registered in the PROSPERO database before the start of the review process (CRD number 42013006565).

Introduction
Living donor nephrectomy is an unusual surgical procedure, since it is performed in healthy individuals. Therefore, it is important that the kidney retrieval procedure is as safe and comfortable as possible, without compromising the function of the graft. In 1954 the first open donor nephrectomy was performed by Murray et al. [1]. For many years the technique remained similar, until 1995 when the first laparoscopic donor nephrectomy (LDN) was performed by Lloyd Ratner and Louis Kavoussi [2]. Thereafter several randomized clinical trials have been conducted and showed that LDN was associated with less pain, with equivalent number of complications and perioperative events as compared to the (mini-incision) open technique [3–7]. Although LDN is associated with a longer first warm ischemia time (WIT1), this was not associated with worsening of initial graft function. Based on best available literature nowadays, LDN is considered to be the technique of first choice in western countries [8].

After the introduction of laparoscopic donor nephrectomy, other technique modifications followed: in 1998 the first case of hand-assisted laparoscopic donor nephrectomy (HALDN) was performed [9]. Hand-assistance has not only the theoretical advantage of direct tactile feedback, but also the possibility of manual dissection. The retroperitoneoscopic approach may reduce the risk of injury to the bowel or other visceral organs. Visceral injuries are the second most frequent complications in laparoscopic urological procedures, second to vascular injuries [10]. In 1994 the first retroperitoneoscopic donor nephrectomy was performed and in 2002 the retroperitoneoscopic approach and hand-assistance were combined [11–12].

To date, several modifications of the standard transperitoneal laparoscopic approach have been applied, including: hand-assisted transperitoneal laparoscopic, total retroperitoneoscopic, hand-assisted retroperitoneoscopic, laparoendoscopic single site (LESS) and the natural orifice (NOTES) approach. All technique modifications claim to have specific advantages. Advantages of hand-assistance are the possibility of manual compression in case of bleeding, quicker
kidney removal and better spatial orientation, in theory leading to less blood loss (EBL), shorter WIT1 and shorter operation time (ORT) when compared to conventional laparoscopy [13]. The retroperitoneal access theoretically lowers the risk of injuries to intra-abdominal organs [14,15]. Others claim LESS is associated with quicker postoperative recovery, less pain and better cosmetic outcome because the entire incision is hidden in the umbilicus [16,17].

Many studies comparing technique modifications of LDN with the standard laparoscopic approach have been performed, varying from relatively small case series to randomized clinical trials [13,16–18]. To determine which technique is “best”, it is important that all outcome measures that are critical or important for decision making, are carefully balanced from the donors’ perspective. Therefore, a systematic review and meta-analysis (SRMA) is indicated to compare the effectiveness of different technique modifications in laparoscopic donor nephrectomy.

Methods

A systematic review and meta-analysis (SMRA) was performed in accordance with the PRISMA (Preferred Reporting Items for Systematic reviews and meta-analyses) [19] guidelines and used a predetermined protocol, registered in PROSPERO (www.crd.york.ac.uk/prospero, CRD number 42013006565) [20].

Search

The Cochrane Central Register of Controlled Trials (CENTRAL) in the Cochrane Library, PubMed, EMBASE and Web of Science were searched from January 1st, 1997. The search was performed on March 1st 2013 and was updated on April 1st 2014. The search strategy is provided in Table 1. No limits regarding language, blinding or publication status were used. The references of the identified trials and cross references were searched to identify any further relevant

Table 1. Search strategy.

| Database       | Search strategy                                                                 |
|----------------|---------------------------------------------------------------------------------|
| PubMed         | (“Tissue Donors”[Mesh] OR “living donors”[Mesh] OR (live[tiab] or living[tiab]) AND donor [tiab]) OR (live[tiab] OR living[tiab]) AND kidney[tiab] AND “kidney transplantation”[Mesh] OR “nephrectomy”[Mesh] OR kidney[tiab] OR kidneys[tiab] OR renal[tiab]) AND (“laparoscopy”[Mesh] OR laparoscopy*[tiab] OR laparoendoscopy*[tiab] OR laparo-endoscopy*[tiab] OR RALDN[tiab] OR RADN[tiab] OR RALN[tiab] OR HAL[tiab] HALDN[tiab] OR HALN[tiab] OR HLQN[tiab] OR LDN[tiab] OR SPL[tiab] OR HARP*[tiab] OR retro-peritoneoscopy*[tiab] OR trans-peritoneoscopy*[tiab] OR extra-peritoneoscopy*[tiab] OR retroperitoneoscopy*[tiab] OR transperitoneoscopy*[tiab] OR extraperitoneoscopy*[tiab] OR single-port[tiab] OR single port[tiab]) |
| Embase         | Living donor OR kidney donor OR (live:ti,ab OR living:ti,ab) AND (donor:ti,ab OR donors: ti,ab)) OR ((live:ti,ab OR living:ti,ab) AND kidney:ti,ab) OR (kidney transplantation OR nephrectomy OR kidney:ti,ab OR kidneys:ti,ab OR renal:ti,ab) AND (exp* laparoscopy OR laparoscopy* OR laparoendoscopy* OR laparo-endoscopy* OR RALDN OR RADN OR RALN OR HAL OR HALDN OR HLQN OR LDN OR SPL OR HARP OR retro-perito* OR transperito* OR extra-perito* OR retroperito* OR extra-perito* OR single-port OR single port) |
| Web of science | TS = (((Live OR living*) AND (donor OR donors)) OR ((live OR living*) AND kidney*) AND (nephrectomy OR kidney OR kidneys OR renal) AND (laparoscopy* OR laparoendoscopy* OR laparo-endoscopy* OR RALN OR RADN OR RALN OR HALN OR HALDN OR HLQN OR LDN OR SPL OR HARP OR retro-peritoneoscopy* OR trans-peritoneoscopy* OR extra-peritoneoscopy* OR retroperitoneoscopy* OR transperitoneoscopy* OR extraperitoneoscopy* OR single-port OR single port)) |

[tiab]: word in title or abstract
(mesh): medical subheading, controlled vocabulary as used by National Library or Medicine for indexing articles
*: truncation; retrieves all possible suffix variations of root word indicated

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randomized clinical trials or cohort studies. When multiple studies describing the same population were published, the most complete report was used.

Study selection
Two authors (DÖ and ME) independently confirmed the eligibility of studies and collected the data from the qualifying studies. Potentially relevant studies were obtained and the full text was examined. Studies were eligible if the standard transperitoneal laparoscopic technique was compared to one of the technique modifications (i.e. hand-assisted (HALDN), retroperitoneoscopic (RDN), hand-assisted retroperitoneoscopic (HARDN) or laparoendoscopic donor nephrectomy (LESS) and at least one of the quantitative outcome measures mentioned in the next section of this paper was included. Standard LDN was performed by a transperitoneal approach in the peritoneal cavity, while retroperitoneoscopic donor nephrectomy (RDN) was performed in the retroperitoneal space. Hand-assistance was performed by introduction of the surgeon’s hand in the peritoneal cavity or retroperitoneal space to facilitate the dissection and extraction of the kidney. In LESS the procedure is performed through a single port that was introduced through the umbilicus.

Studies published only as abstracts were excluded, because a thorough quality assessment could not be performed, also case series with less than 10 patients were excluded. Allowed study designs were: randomized clinical trials and comparative prospective or retrospective cohort studies.

Data extraction
For each included trial the following characteristics were extracted: year of publication, country and city (or cities), single- or multicenter design, study design, total number of patients, total number of patients in each treatment arm, mean age and standard deviation, gender, mean body mass index (BMI) and standard deviation and number of left donor nephrectomies.

The primary outcome measure was the number of complications. Secondary outcome measures include: conversion to open donor nephrectomy (ODN), WIT1 (seconds), EBL (mL), graft function, ORT (minutes) and length of hospital stay (LOS) (days). Graft function was reflected by the incidence of delayed graft function (DGF). DGF was defined as the need for dialysis in the first week after transplantation, excluding dialysis for hyperkalemia [21].

In case of missing data, the corresponding author was addressed for more information. In case the authors did not reply, the standard deviation was reconstructed from the mean and range, if sufficient data was available.

Risk of bias assessment
For randomized clinical trials a quality assessment was performed according to the Cochrane Risk of Bias Tool [22]. For the non-randomized trials the quality assessment was performed using the adapted Newcastle Ottawa Rating scale, which consists of three factors: patient selection, comparability of study groups and assessment of outcome [23]. In this adapted quality assessment scale a maximum of 7 stars could be scored; 6 or 7 stars corresponded with high quality, 4 or 5 stars with intermediate quality and 0 to 3 stars with low quality. The quality assessments were performed by two authors (DÖ and ME) independently. In case of discrepancies, consensus was reached by discussion.
Statistical methods

The meta-analysis for randomized clinical trials and cohort studies separately was performed using Review Manager (version 5.2 The Cochrane Collaboration, Oxford, UK). When the mean difference or odds ratio of the randomized clinical trial coincided with the 95% CI of the cohort studies, the data were pooled.

Data was pooled with a random effects meta-analysis with odds ratios, weighted mean differences and their corresponding 95% CIs. To assess heterogeneity in results of individual studies, the $I^2$ statistic was used ($I^2 > 75\%$ was used as a threshold indicating significant heterogeneity). Reasons for heterogeneity were explored. Publication bias was assessed with Funnel plots and Egger’s regression model. All analyses were performed on an intention-to-treat bias.

Sensitivity analysis

For the sensitivity analysis, the poor quality studies were excluded. For each technique modification, the trials were divided in two equal groups based on the year of publication (earliest and latest) and all outcome measures were re-analyzed, i.e. the results of an initial group were compared to the results of the second (last) group. Also the data was re-analyzed with regard to the number of complications for each technique modification after excluding all mild complications per study. For this, all individual complications were classified according to their estimated severity (i.e. severe, moderate or mild). Severe complications were defined as (potentially) live-threatening events, (multi-) organ failure or events necessitating admission to the Intensive Care Unit. Events (potentially) requiring an intervention or surgery were defined as moderate complications. Mild complications only required non-surgical or conservative management.

Results

Search results

The search strategy identified 509 potential eligible studies, the titles and abstracts were screened for inclusion. The full text of 137 articles was retrieved, of which 31 met the inclusion criteria. Reasons for exclusion of the remaining articles were: not full-text available ($n = 2$), the study group contained less than 10 patients ($n = 5$), irrelevant endpoint ($n = 8$), other urological procedures were also included ($n = 15$) or because LDN was not included in the comparison ($n = 76$).

Fig. 1 shows the characteristics of the 31 included studies. Sixteen studies compared HALDN versus LDN, 4 studies compared RDN versus LDN, 4 compared HARDN versus LDN and 7 studies compared LESS versus LDN, study characteristics are shown in Table 2 and 3. 25 Authors were contacted by e-mail for additional information, one author provided additional information. Table 4 and 5 show the risk of bias for all included trials and cohort studies, respectively. The overall quality of the included studies was low to moderate.

HALDN versus LDN

Sixteen studies (2 randomized clinical trials and 14 cohort studies) compared HALDN to LDN (Fig. 2) [18,24–38]. No differences were found in the number of complications, conversion to ODN, EBL, graft function and LOS (Fig. 2A, 2B, 2D, 2E and 2G). Graft function was only studied in 4 cohort studies (Fig. 2E). WIT1 and ORT were shorter in HALDN as compared to LDN (MD = -52.9, 95%CI: -91.6 - -14.3, $I^2 = 96\%$ and MD = -18.3, 95%CI: -32.9 - -3.6, $I^2 = 94\%$, respectively) (Fig. 2C and 2F).
RDN versus LDN

Four (cohort) studies compared RDN to LDN (Fig. 3) [39–41]. A tendency towards less complications was seen in the RDN group (OR = .5, 95%CI 2–1.1, I² = 23%) (Fig. 3A). With regard to the intra-abdominal injuries, studies comparing RDN with LDN described 1 splenic and 2
bowel injuries, all occurring in the LDN group. Conversion to ODN, WIT1, EBL, ORT and LOS did not differ between both types of intervention (Fig. 3B, 3C, 3D, 3E and 3F). Graft function could, due to insufficient data, not be analyzed (data not shown).

**HARDN versus LDN**

Three cohort studies and 1 randomized clinical trial compared HARDN to LDN (Fig. 4) [34,39–42]. A tendency towards less complications was found in the HARDN group when compared to LDN (OR = .6, 95%CI 3–1.1, I² = 0%) (Fig. 4A), all intra-abdominal injuries occurred in the LDN group (i.e. 2 splenic and 3 bowel injuries). No differences in the number of

### Table 2. Characteristics of randomized clinical trials.

| Author       | Year of publication | Country/ State   | Comparison* | Number of patients (LDN vs technique modification) |
|--------------|---------------------|------------------|-------------|-----------------------------------------------|
| Bargman [18] | 2006                | US/Indiana       | HALDN       | 20 vs. 20                                    |
| Cho [25]     | 2013                | Korea            | HALDN       | 50 vs. 50                                    |
| Dols [42]    | 2014                | the Netherlands  | HARDN       | 95 vs. 95                                    |
| Kurien [17]  | 2011                | India            | LESS        | 25 vs. 25                                    |
| Richstone [43]| 2013                | US/New York     | LESS        | 14 vs. 15                                    |

* with LDN as reference

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### Table 3. Characteristics of cohort studies.

| Study        | Year of publication | Country/ State   | Comparison(s)* | Number of patients (technique modifications versus LDN) |
|--------------|---------------------|------------------|----------------|--------------------------------------------------------|
| Afaneh [16]  | 2011                | US/New York      | LESS           | 50 vs. 15 (vs 25)                                      |
| Barth [45]   | 2013                | US/Maryland      | LESS           | 6 vs. 6                                               |
| Branco [24]  | 2008                | Brazil           | HALDN          | 67 vs. 89                                             |
| Canes [46]   | 2010                | US/Vermont       | LESS           | 17 vs. 17                                             |
| El-Galley [26]| 2004               | United Kingdom   | HALDN(ODN)     | 55 vs. 17 (vs 28)                                     |
| Gao [39]     | 2007                | China            | RDN            | 19 vs. 28                                             |
| Gershbein [27]| 2002               | US/California    | HALDN          | 15 vs. 30                                             |
| Gjersten [47]| 2006                | US/New York      | HARDN (ODN)    | 11 vs. 15 (vs 25)                                     |
| Kocak [28]   | 2007                | US/Illinois      | HALDN          | 318 vs. 482                                           |
| Lai [29]     | 2010                | Taiwan           | HALDN          | 45 vs 52                                              |
| Lunsford [44]| 2011                | US/California    | LESS           | 10 vs. 20                                             |
| Mateo [30]   | 2003                | US/California    | HALDN          | 18 vs. 29                                             |
| Mjoen [31]   | 2009                | Norway           | HALDN/HARDN    | 177 vs. 26 vs. 196                                    |
| Ng [40]      | 2004                | US/Cleveland     | RDN            | 36 vs. 107                                            |
| Percegona [32]| 2008               | Brazil           | HALDN          | 34 vs. 21                                             |
| Ruiz-Deya [33]| 2001               | US/Louisiana     | HALDN          | 11 vs. 23                                             |
| Rusztat [34]| 2006                | Switzerland      | HALDN/RDN(ODN) | 33 vs. 63 vs. 12 (vs 69)                              |
| Salazar [35]| 2005                | Canada           | HALDN(ODN)     | 15 vs. 24 (vs. 11)                                    |
| Srivastava [41]| 2008               | India            | RDN            | 38 vs. 342                                            |
| Stamatakis [47]| 2013               | Texas            | LESS           | 102 vs. 111                                           |
| Ungbhakorn [36]| 2012              | Thailand         | HALDN(ODN)     | 23 vs. 82 (vs. 95)                                    |
| Velidedeoglu [37]| 2002             | US/Pennsylvania  | HALDN(ODN)     | 60 vs. 40 (vs. 50)                                    |
| Wadströmm [38]| 2003               | Sweden           | HALDN/HARDN    | 14 vs. 18 vs. 11                                      |

* with LDN as reference

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Table 4. Risk of bias assessment for randomized clinical trials.

|                  | Random sequence generation | Allocation concealment | Blind of participants and personnel (performance bias) | Blinding of outcome assessment (detection bias) | Incomplete outcome data (attrition bias) | Selective reporting (reporting bias) | Funding | Other bias |
|------------------|----------------------------|------------------------|--------------------------------------------------------|-----------------------------------------------|----------------------------------------|-------------------------------------|---------|------------|
| Bargman [18]     | ?                         | ?                      | -                                                      | ?                                             | +                                     | +                                   | +       | None       |
| Cho [25]         | -                         | ?                      | -                                                      | +                                             | +                                     | +                                   | None    | None       |
| Dols [42]        | +                         | ?                      | +                                                      | ?                                             | +                                     | +                                   | None    | None       |
| Kurien [17]      | ?                         | ?                      | ?                                                      | +                                             | +                                     | +                                   | None    | Experience of the surgeon with less technique unclear.Inclusion of patients with high BMI during the study |
| Richstone [43]   | +                         | +                      | +                                                      | ?                                             | -                                     | +                                   | None    | Premature terminationExperience with LESS is unclear |

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Table 5. Quality assessment of cohort studies.

|                  | Comparability | Exposure | Total |
|------------------|---------------|----------|-------|
|                  | Representativeness | Follow up | Comparability | Ascertainment | Same method | Non response rate |
| HALDN            |               |          |       |
| Branco [24]      | +             | *        | +     | +             | +           | 5          |
| El-Galley [28]   | +             | *        | +     | +             | +           | 4          |
| Gershbein [27]   | +             | *        | +     | +             | +           | 4          |
| Kocak [28]       | +             | *        | +     | +             | +           | 5          |
| Lai [29]         | +             | *        | +     | +             | +           | 5          |
| Mateo [30]       | +             | *        | +     | +             | +           | 4          |
| Mjoen [31]       | +             | *        | +     | +             | +           | 4          |
| Percegona [32]   | +             | *        | +     | +             | +           | 4          |
| Ruiz-Deya [33]   | +             | *        | +     | +             | +           | 4          |
| Ruszat [34]      | +             | *        | +     | +             | +           | 4          |
| Salazar [35]     | +             | *        | +     | +             | +           | 4          |
| Ungbhakorn [36]  | +             | *        | +     | +             | +           | 4          |
| Velidedeoglu [37]| +             | *        | +     | +             | +           | 4          |
| Wadstrom [38]    | +             | *        | +     | +             | +           | 4          |
| RDN              |               |          |       |
| Gao [39]         | +             | *        | +     | +             | +           | 4          |
| Ng [40]          | +             | *        | +     | +             | +           | 4          |
| Ruszat [34]      | +             | *        | +     | +             | +           | 4          |
| Srivastava [41]  | +             | *        | +     | +             | +           | 3          |
| HARDN            |               |          |       |
| Mjoen [31]       | +             | *        | +     | +             | +           | 4          |
| Gjertsen [47]    | +             | *        | +     | +             | +           | 3          |
| Wadstrom [38]    | +             | *        | +     | +             | +           | 4          |
| LESS             |               |          |       |
| Afaneh [16]      | +             | *        | *     | +             | +           | 6          |
| Barth [45]       | +             | *        | +     | +             | +           | 5          |
| Canes [46]       | +             | *        | +     | +             | +           | 5          |
| Lunsford [44]    | +             | *        | +     | +             | +           | 4          |
| Stamatakis [47]  | +             | *        | +     | +             | +           | 5          |

0–3 low quality  
4–5 intermediate quality  
6–7 high quality

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### Table: Study Details and Odds Ratio

| Study or Subgroup | Events | Total | Weight | Odds Ratio | 95% CI | Odds Ratio | 95% CI |
|-------------------|--------|-------|--------|------------|--------|------------|--------|
| **LapN** | **OR** | **OR** |
| **Study or Subgroup** | **Events** | **Total** | **Weight** | **OR** | **95% CI** | **OR** | **95% CI** |
| **Bartmann, 2004** | 28 | 5 | 20 | 6.2 | 0.03 (0.11, 1.3) | | |
| **Braun, 2008** | 6 | 6 | 3 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Chen, 2013** | 3 | 3 | 2 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Fricke, 2004** | 6 | 6 | 2 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Hase, 2005** | 45 | 45 | 22.1 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Hassler, 2005** | 21 | 21 | 10.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Marx, 2008** | 3 | 3 | 2 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Marx, 2009** | 24 | 24 | 12 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Pennacchi, 2008** | 9 | 9 | 4.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Rath-Deller, 2001** | 3 | 3 | 1.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Rutkowska, 2004** | 10 | 10 | 5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Ugoliki, 2008** | 3 | 3 | 1.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Volkers, 2002** | 2 | 2 | 1 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Wolfgang, 2003** | 1 | 1 | 0.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Total events** | 119 | 119 | 60 | 1.0 | 0.01 (0.02, 0.05) | | |

**Heterogeneity:** $\chi^2 = 3.89, df = 10, p = 0.60, P = 0.10$; Test for overall effect: $I^2 = 0.00 (p = 0.90)$

### Table: Study Details and Odds Ratio

| Study or Subgroup | Events | Total | Weight | Odds Ratio | 95% CI | Odds Ratio | 95% CI |
|-------------------|--------|-------|--------|------------|--------|------------|--------|
| **LapN** | **OR** | **OR** |
| **Study or Subgroup** | **Events** | **Total** | **Weight** | **OR** | **95% CI** | **OR** | **95% CI** |
| **Bartmann, 2004** | 8 | 8 | 4 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Braun, 2008** | 26 | 26 | 13 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Chen, 2013** | 24 | 24 | 12 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Fricke, 2004** | 10 | 10 | 5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Hase, 2005** | 12 | 12 | 6 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Hassler, 2005** | 6 | 6 | 3 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Marx, 2008** | 18 | 18 | 9 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Marx, 2009** | 12 | 12 | 6 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Pennacchi, 2008** | 9 | 9 | 4.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Rath-Deller, 2001** | 3 | 3 | 1.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Rutkowska, 2004** | 10 | 10 | 5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Ugoliki, 2008** | 3 | 3 | 1.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Volkers, 2002** | 2 | 2 | 1 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Wolfgang, 2003** | 1 | 1 | 0.5 | 1.0 | 0.01 (0.02, 0.05) | | |
| **Total events** | 119 | 119 | 60 | 1.0 | 0.01 (0.02, 0.05) | | |

**Heterogeneity:** $\chi^2 = 3.89, df = 10, p = 0.60, P = 0.10$; Test for overall effect: $I^2 = 0.00 (p = 0.90)$

### Diagram: Comparison of Techniques

The diagram compares the performance of different laparoscopic techniques in donor nephrectomy. Each bar represents a study, with the height indicating the effect size (odds ratio) and the width indicating the confidence interval. The bars are color-coded to indicate the study's results. The diagram is divided into two main sections: **LapN** and **OR**.
conversions to ODN or graft function were found (Fig. 4B). WIT1 and ORT were shorter in HARDN as compared to LDN (MD = -109.4, 95%CI -152.7 - -66.1, I² = 74% and MD = -38.6, 95%CI -60.8- -16.5, I² = 79%, respectively), Fig. 4C and 4D).

LESS versus LDN

Seven studies, 2 randomized clinical trials [17,43] and 5 cohort studies [16,44–47] compared LESS and LDN (Fig. 5). There was no difference in the number of complications, conversions to ODN, WIT1 and LOS (Fig. 5A, 5B, 5C and 5F). Less EBL was seen in LESS as compared to LDN (MD = -19.1, 95%CI -27.5 - -10.8, I² = 0%), while OR time was shorter in LDN as compared to LESS (MD = 19.8, 95%CI 8.9–30.7, I² = 67%) (Fig. 5D and 5E).

Retroperitoneal versus transperitoneal approach

When the complications of both retroperitoneal approaches (HARDN and RDN) were combined and compared to the transperitoneal approach, the retroperitoneoscopic approaches were associated with significantly less complications, Fig. 6 (OR 0.52, 95%CI 0.33–0.83, I² = 0%).

Hand-assisted versus fully laparoscopic approach

No significant difference in the number of complications was demonstrated when the hand-assisted techniques (HALDN and HARDN) were combined and compared to the fully laparoscopic technique, Fig. 7 (OR 0.52, 95% CI 0.33–0.83, I² = 46%).

Sensitivity analysis

For the sensitivity analysis, the poor quality cohort studies (less than 3 points) were excluded [38, 40, 41]. Since 2 of the 3 studies that had to be excluded compared RDN with LDN, which included only 4 studies, insufficient data remained for a meaningful analysis. No significant changes occurred when the third study was excluded from the analysis.

Also, the results of the initial trials, were compared to the last group. Subsequently, two meta-analyses changed: the first group of published studies comparing HALDN to LDN showed less complications in favor of HALDN (OR = .45, 95%CI.23–.88, I² = 0%), Fig. 8A and B. Regarding EBL, no significant differences were found in the first group of published studies comparing LESS and LDN (MD = -17.9, 95%CI -26.7 - -9.1, I² = 0%) (data not shown).

In Table 6 the severity of complications for each technique modification is shown. Injuries of intraperitoneal organs only occurred in techniques with a transperitoneal approach (i.e. LDN, HALDN and LESS). When all mild complications were excluded from the analysis there
### Complications

| Study or Subgroup | RDN Events | LDN Events | Weight | Odds Ratio (M-H, Random, 95% CI) | Odds Ratio (M-H, Random, 95% CI) |
|-------------------|------------|------------|--------|---------------------------------|---------------------------------|
| Gao, 2007         | 2          | 2          | 1      | 1.01 (0.08, 1.22)               | 0.98 (0.22, 1.21)               |
| Ng, 2004          | 2          | 3          | 1.07   | 1.00 (0.05, 2.24)               | 1.20 (0.22, 6.57)               |
| Ruzaszt, 2006     | 2          | 3          | 0.98   | 0.20 (0.006, 0.66)              | 0.47 (0.16, 1.39)               |
| Siinostava, 2009  | 105        | 82         | 100.00 | 0.48 (0.21, 1.09)               |                                 |
| Total (95% CI)    | 21         | 105        |        |                                 |                                 |

Heterogeneity: Tau² = 0.17, Ch² = 3.91, df = 3 (P = 0.27), p² = 23%
Test for overall effect: Z = 1.75 (P = 0.08)

### Conversion to open donor nephrectomy

| Study or Subgroup | RDN Events | LDN Events | Weight | Odds Ratio (M-H, Random, 95% CI) |
|-------------------|------------|------------|--------|---------------------------------|
| Gao, 2007         | 1          | 2          | 1.00   | 2.13 (0.08, 55.02)              |
| Ruzaszt, 2006     | 2          | 12         | 2.89   | 0.16 (0.02, 1.30)               |
| Siinostava, 2009  | 2          | 12         | 1.83   | 1.53 (0.33, 7.16)               |
| Total (95% CI)    | 5          | 373        |        | 0.75 (0.15, 3.68)               |

Heterogeneity: Tau² = 0.79, Ch² = 3.29, df = 2 (P = 0.19), p² = 39%
Test for overall effect: Z = 0.35 (P = 0.72)

### First warm ischemia time

| Study or Subgroup | RDN Mean [seconds] | SD [seconds] | Total | RDN Mean [seconds] | SD [seconds] | Total | Mean Difference (M-H, Random, 95% CI) |
|-------------------|--------------------|-------------|-------|--------------------|-------------|-------|-------------------------------------|
| Gao, 2007         | 122                | 28          | 102   | 26                 | 19          | 34.5% | 0.00 (4.12, 35.88)                   |
| Ruzaszt, 2006     | 121                | 63          | 238   | 69                 | 12          | 32.2% | -117.00 (-157.21,-76.78)            |
| Siinostava, 2009  | 210                | 38          | 270   | 120                | 342         | 33.3% | -60.00 (-91.31,-28.69)              |
| Total (95% CI)    | 373                | 100.00      |       |                    |             |       | -50.77 [-132.59, 31.04]             |

Heterogeneity: Tau² = 4948.24, Ch² = 59.71, df = 2 (P < 0.0001), p² = 96%
Test for overall effect: Z = 1.22 (P = 0.22)

### Estimated blood loss

| Study or Subgroup | RDN Mean [mL] | SD [mL] | Total | RDN Mean [mL] | SD [mL] | Total | Mean Difference (M-H, Random, 95% CI) |
|-------------------|---------------|--------|-------|---------------|--------|-------|-------------------------------------|
| Gao, 2007         | 54            | 10     | 20    | 11            | 16     | 45.7% | 0.00 (-10.16, 2.16)                 |
| Ruzaszt, 2006     | 117           | 63     | 307   | 159           | 12     | 12.6% | -136.00 (-229.97,-42.03)            |
| Siinostava, 2008  | 115           | 38     | 85    | 50            | 342    | 42.4% | 30.00 (13.24, 46.78)                |
| Total (95% CI)    | 373           | 100.00 |       |               |         |       | -5.39 [-43.13, 32.27]               |

Heterogeneity: Tau² = 802.27, Ch² = 21.84, df = 2 (P < 0.0001), p² = 91%
Test for overall effect: Z = 0.28 (P = 0.78)

### Operation time

| Study or Subgroup | RDN Mean [minutes] | SD [minutes] | Total | RDN Mean [minutes] | SD [minutes] | Total | Mean Difference (M-H, Random, 95% CI) |
|-------------------|--------------------|-------------|-------|--------------------|-------------|-------|-------------------------------------|
| Gao, 2007         | 102                | 32          | 82    | 22                 | 19          | 33.7% | 20.00 (4.56, 35.44)                 |
| Ruzaszt, 2006     | 150                | 63          | 212   | 34                 | 12          | 32.0% | -62.00 (-94.74, -30.66)             |
| Siinostava, 2008  | 192                | 35          | 180   | 45                 | 342         | 34.3% | 12.00 (-0.11, 24.11)                |
| Total (95% CI)    | 373                | 100.00      |       |                    |             |       | -9.00 [-50.15, 32.15]               |

Heterogeneity: Tau² = 1246.89, Ch² = 39.30, df = 2 (P < 0.0001), p² = 95%
Test for overall effect: Z = 0.43 (P = 0.67)

### Length of hospital stay

| Study or Subgroup | RDN Mean [days] | SD [days] | Total | RDN Mean [days] | SD [days] | Total | Mean Difference (M-H, Random, 95% CI) |
|-------------------|-----------------|----------|-------|-----------------|----------|-------|-------------------------------------|
| Gao, 2007         | 6.8             | 2.1      | 29    | 6.1             | 1.7      | 54.0% | 0.70 (0.19, 1.78)                   |
| Ruzaszt, 2006     | 150             | 63       | 212   | 34               | 12       | 32.0% | -62.00 (-94.74, -30.66)             |
| Siinostava, 2008  | 192             | 35       | 180   | 45               | 342      | 34.3% | 12.00 (-0.11, 24.11)                |
| Total (95% CI)    | 81              | 100.00   |       |                 |           |       | -0.52 [-3.16, 2.11]                |

Heterogeneity: Tau² = 2.99, Ch² = 5.55, df = 1 (P = 0.02), p² = 82%
Test for overall effect: Z = 0.39 (P = 0.70)

### Fig 3. Forrest plots comparing RDN versus LDN (RCT’s and cohort studies combined).

a. Complications of RDN versus LDN. Four studies compared complications in RDN versus LDN (OR 0.48, 95% CI 0.21–1.09, I² = 23%), there was a tendency towards less complications for RDN.

b. Conversion to ODN in RDN versus LDN. Three studies compared the number of conversions to ODN in RDN versus LDN (OR 0.75, 95% CI 0.15–3.68, I² = 39%).

c. WIT1 in RDN versus LDN. Three studies described WIT1 in RDN versus LDN (MD -50.77, 95%CI -132.59–31.04, I² = 96%).

D. EBL in RDN versus LDN. Three
were still significantly less complications in the retroperitoneoscopic group as compared to the transperitoneal group (OR = .51, 95CI %. 28-.92, I² = 0%) (data not shown).

**Publication bias**

Funnel plots showed possible publication bias for the comparison of the number of complications in the retroperitoneal versus the transperitoneal group (Fig. 9E). The remaining funnel
Fig 5. Forrest plots comparing LESS versus LDN (RCT and cohort studies combined). a. Complications of LESS versus LDN. Five studies compared the number of complications in LESS versus LDN (OR 1.08, 95%CI 0.62–1.87, I² = 0%). b. Conversion to ODN in LESS versus LDN. Two studies compared the number of conversion to ODN in LESS versus LDN (OR 1.17, 95%CI 0.06–23.59, I² = 45%). c. WIT1 (seconds) in LESS versus LDN. Five studies described WIT1 in LESS versus LDN (MD 51.53, 95%CI -12.45–115.51, I² = 94%). d. EBL (mL) in LESS versus LDN. Three studies described EBL in LESS versus LDN.
plots were either symmetric or contained insufficient data for meaningful analysis (Fig. 9A, 9B, 9C, 9D and 9F).

**Discussion**

This meta-analysis shows that the retroperitoneoscopic approach is associated with less complications as compared to the transperitoneal approach. In fact, when comparing the retroperitoneoscopic approach with LDN, all intra-abdominal injuries occurred in the transperitoneal LDN group.

The data also show that hand-assistance, either through the transperitoneal or retroperitoneal approach, is associated with shorter WIT1 and ORT. Obviously, the association with shorter WIT1 can be explained by the fact that HALDN includes a direct kidney retrieval without the use of an endobag. Nevertheless, there was considerable heterogeneity between the studies regarding WIT1 ($\chi^2 = 93\%$). In contrast with the other studies, WIT1 described by Branco et al. was remarkably increased in the HALDN group as compared to the standard laparoscopic donor nephrectomy group [24]. Most likely due to a later introduction HALDN, after the initial learning curve with LDN. The association of HALDN with shorter ORT can be explained by the fact that in most studies the surgeons went through their initial learning curve with LDN. However, in three studies, in which ORT was longer for HALDN, no information was provided regarding the learning curve of each separate technique modification.

With regard to the assumption that hand-assistance leads to easier control in case of bleeding, it is remarkable to note that both the HALDN and HARDN technique were not associated with reduced EBL. This may indicate that hand-assistance may not be a major determinant of EBL.

In general, the single port technique is technically more demanding as compared to the three (or four) port approach. Therefore, it is likely to assume that the single port procedures

| Study or Subgroup | Retropitoneal Events | Transperitoneal Events | Total | Weight | Odds Ratio M-H, Random, 95% CI | Odds Ratio M-H, Random, 95% CI |
|-------------------|----------------------|------------------------|-------|--------|------------------------------|------------------------------|
| Dols, 2014 (RCT)  | 13                   | 95                     | 108   | 38.3%  | 0.63 [0.29, 1.37]             |                              |
| Gao, 2007         | 2                    | 28                     | 30    | 3.5%   | 1.38 [0.12, 16.44]            |                              |
| Gjertsen, 2006    | 2                    | 11                     | 13    | 3.3%   | 3.11 [0.24, 39.54]            |                              |
| Mjoen, 2010       | 3                    | 26                     | 29    | 13.3%  | 0.31 [0.09, 1.12]             |                              |
| Ng, 2004          | 2                    | 36                     | 38    | 7.8%   | 1.20 [0.22, 6.47]             |                              |
| Ruszt, 2006       | 13                   | 63                     | 76    | 14.5%  | 0.20 [0.06, 0.66]             |                              |
| Srivastava 2008   | 4                    | 38                     | 42    | 18.9%  | 0.47 [0.16, 1.38]             |                              |
| Wadström, 2003    | 1                    | 18                     | 19    | 2.6%   | 0.59 [0.03, 10.48]            |                              |
| **Total (95% Cl)**| **40**               | **133**                | **173**| **100.0%** | **0.52 [0.33, 0.83]** | **0.01 [0.01, 1.00]** |

Heterogeneity: $\chi^2 = 6.82$, df = 7 ($P = 0.45$); $I^2 = 0\%$
Test for overall effect: $Z = 2.73$ ($P = 0.006$)

Fig 6. Forest plot comparing the number of complications in the retroperitoneoscopic group (HARDN and RDN) versus the transperitoneal approach. The number of complications was significantly lower in the retroperitoneoscopic group (OR 0.52, 95% CI 0.33–0.83, $p < 0.01$).
were performed by skilled surgeons, this may explain why LESS was associated with significantly less blood loss. When trials were divided in two equal groups based on year of publication, the earliest studies (2001–2006) comparing HALDN and LDN showed less complications in favor of HALDN [24, 25, 27, 28, 31, 32, 36]. This suggests that HALDN is a safer technique for surgeons of centers in their learning curve.

Strengths and limitations

The major strengths of this SRMA is the systematic approach with a protocol published in advance and a relatively large number of studies included. A comprehensive assessment is provided of 4 different technique modifications of laparoscopic donor nephrectomy that is relevant to both clinicians and patients. The presented data provide a complete overview of current literature and reveals the gaps in evidence. Several limitations should be discussed. First, the results should be interpreted cautiously, in general, the quality of the included cohort studies and RCTs was low to intermediate or unclear. For 3 randomized clinical trials the risk of bias was high [18, 25, 43], for the remaining 2 trials the risk of bias was unclear [17, 42]. Assessment of the cohort studies revealed that the overall quality was low to intermediate. Second, considerable heterogeneity in most studies was observed. This may be explained by differences in experience and learning curve. In all studies, very limited or no information regarding experience of the surgeons of each separate technique modification was provided. Third, publication bias cannot be excluded, as asymmetry in one funnel plot was found, while most funnel plots

Fig 7. Forest plot comparing the number of complications in the hand-assisted versus the fully laparoscopic donor nephrectomy. No difference in complications was found (OR 0.76, 95% CI 0.49–1.19, p = 0.23).

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contained insufficient data for meaningful evaluation. Fourth, as many studies described their early experience with new technique modifications a certain degree of confounding by indication may have occurred. However, in most studies there were no significant differences in baseline characteristics between the treatment groups including age, gender, BMI, multiple renal arteries and side of nephrectomy. Finally, relevant outcome measures such as postoperative pain and quality of life were not included in the analyses, as these variables were poorly reported.

Implications for clinical practice
The data show that the retroperitoneoscopic approach is associated with less complications. Furthermore, hand assistance was associated with less complications in the earliest studies.
## Table 6. Complications and estimation of severity.

|                     | LDN (n = 1802) | HALDN (n = 870) | RDN (n = 165) | HARDN (n = 150) | LESS (n = 209) |
|---------------------|----------------|-----------------|---------------|-----------------|----------------|
| **Intra-operative complications** |                 |                 |               |                 |                |
| Severe              |                 |                 |               |                 |                |
| Renal and/or caval vein bleeding | 5 (0.3) | 5 (0.6) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Renal artery and/or aortic bleeding | 12 (0.7) | 3 (0.3) | 2 (1.2) | 0 (0.0) | 0 (0.0) |
| Splenic lesion > 500 mL blood loss | 1 (0.1) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Bleeding, undefined > 500 mL blood loss | 1 (0.1) | 0 (0.0) | 0 (0.0) | 4 (2.7) | 0 (0.0) |
| **Subtotal**        | 19 (1.1)       | 8 (0.9)         | 2 (1.2)       | 4 (2.7)         | 0 (0.0) |
| Moderate            |                 |                 |               |                 |                |
| Splenic lesion      | 14 (0.8)        | 1 (0.1)         | 0 (0.0)       | 0 (0.0)         | 2 (1.0) |
| Bladder lesion      | 0 (0.0)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 1 (0.5) |
| Diaphragm lesion    | 2 (0.1)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 1 (0.5) |
| Adrenal hematoma    | 2 (0.1)         | 2 (0.2)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Serosa lesion       | 6 (0.3)         | 2 (0.2)         | 0 (0.0)       | 0 (0.0)         | 1 (0.5) |
| Lumbar vein bleeding| 3 (0.2)         | 1 (0.1)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Adrenal vein bleeding| 4 (0.2)       | 3 (0.3)         | 1 (0.6)       | 0 (0.0)         | 0 (0.0) |
| **Subtotal**        | 31 (1.7)        | 9 (1.0)         | 1 (0.6)       | 1 (0.7)         | 5 (2.4) |
| Mild                |                 |                 |               |                 |                |
| Transient CO2 PNP   | 2 (0.1)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Decapulsation/lesion allograft | 1 (0.1)       | 2 (0.2)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Other               | 7 (0.4)         | 2 (0.2)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| **Subtotal**        | 10 (0.6)        | 4 (0.5)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| **Total**           | 60 (3.3)        | 21 (2.4)        | 3 (1.8)       | 5 (3.3)         | 5 (2.4) |
| Post-operative complications |                 |                 |               |                 |                |
| Severe              |                 |                 |               |                 |                |
| Pancreatitis        | 2 (0.1)         | 2 (0.2)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Myocardial ischemia | 0 (0.0)         | 0 (0.0)         | 1 (0.6)       | 0 (0.0)         | 0 (0.0) |
| Pulmonary embolism  | 0 (0.0)         | 1 (0.1)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Rhabdomyolysis      | 1 (0.1)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| **Subtotal**        | 3 (0.2)         | 2 (0.2)         | 1 (0.6)       | 0 (0.0)         | 0 (0.0) |
| Moderate            |                 |                 |               |                 |                |
| Bowel obstruction   | 20 (1.1)        | 12 (1.4)        | 0 (0.0)       | 0 (0.0)         | 4 (1.9) |
| Atelectasis         | 2 (0.1)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Chylothorax or pleural effusion | 5 (0.3)       | 3 (0.3)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Incisional hernia   | 5 (0.3)         | 2 (0.2)         | 0 (0.0)       | 1 (0.7)         | 0 (0.0) |
| Incisional neurinoma| 1 (0.1)         | 1 (0.1)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Blood transfusion   | 26 (1.4)        | 1 (0.1)         | 3 (1.8)       | 0 (0.0)         | 0 (0.0) |
| Urethral obstruction| 2 (0.2)         | 1 (0.1)         | 1 (0.6)       | 0 (0.0)         | 0 (0.0) |
| Re-operation for (suspect) bleeding | 5 (0.3)       | 1 (0.1)         | 1 (0.6)       | 0 (0.0)         | 0 (0.0) |
| Pneumonia           | 10 (0.6)        | 1 (0.1)         | 2 (1.2)       | 2 (1.3)         | 0 (0.0) |
| Other               | 7 (0.4)         | 1 (0.1)         | 1 (0.6)       | 0 (0.0)         | 1 (0.5) |
| **Subtotal**        | 83 (4.6)        | 23 (4.6)        | 11 (6.7)      | 3 (2.0)         | 5 (2.4) |
| Mild                |                 |                 |               |                 |                |
| Urinary retention   | 6 (0.3)         | 3 (0.3)         | 1 (0.6)       | 0 (0.0)         | 3 (1.4) |
| Wound infection     | 38 (2.1)        | 8 (0.9)         | 3 (1.8)       | 4 (2.7)         | 4 (1.9) |
| Conjunctivitis, corneal abrasion | 0 (0.0)       | 1 (0.1)         | 0 (0.0)       | 0 (0.0)         | 2 (1.0) |
| Scrotal edema       | 1 (0.1)         | 2 (0.2)         | 0 (0.0)       | 1 (0.7)         | 0 (0.0) |
| Chronic pain (wound, testicular) | 4 (0.2)        | 3 (0.3)         | 1 (0.6)       | 0 (0.0)         | 6 (2.7) |
| Subcutaneous hematoma| 5 (0.3)       | 1 (0.1)         | 0 (0.0)       | 1 (0.7)         | 0 (0.0) |
| Wound seroma        | 3 (0.2)         | 0 (0.0)         | 0 (0.0)       | 1 (0.7)         | 0 (0.0) |
| Anemia              | 3 (0.2)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 0 (0.0) |
| Urinary tract infection | 0 (0.0)       | 0 (0.0)         | 0 (0.0)       | 1 (0.7)         | 1 (0.5) |
| Atypical chest pain | 0 (0.0)         | 0 (0.0)         | 0 (0.0)       | 0 (0.0)         | 2 (1.0) |
| Fever               | 2 (0.1)         | 1 (0.1)         | 1 (0.6)       | 0 (0.0)         | 2 (1.0) |
| Other               | 2 (0.1)         | 3 (0.3)         | 0 (0.0)       | 0 (0.0)         | 1 (0.5) |
| **Subtotal**        | 65 (3.6)        | 22 (2.5)        | 6 (3.6)       | 8 (5.3)         | 21 (10.0) |
| **Total**           | 210 (11.7)      | 47 (5.4)        | 18 (10.9)     | 11 (7.3)        | 26 (12.4) |
| Not specified*      | 30 (1.7)        | 21 (2.4)        | 0 (0.0)       | 3 (2.0)         | 0 (0.0) |
| **Total**           | 240 (13.3)      | 89 (10.2)       | 21 (12.7)     | 19 (12.7)       | 31 (14.8) |

* Mjoen et al.[31]

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Therefore, it could be suggested that in centers who are converting from open donor nephrectomy to a minimal invasive, laparoscopic approach, safety may increase by the use of the hand-assisted, retroperitoneoscopic (HARDN) technique.

Conclusion

During laparoscopic kidney retrieval, hand-assistance reduces the operation and first warm ischemia times and may improve safety for surgeons or centers with less experience in laparoscopic donor nephrectomy. The retroperitoneoscopic approach is associated with less complications. However, given the, in general, poor to intermediate quality and considerable heterogeneity in the included studies, further high-quality studies are required.

Author Contributions

Conceived and designed the experiments: DÖ GK MR MW. Performed the experiments: DÖ ME SvH MW. Analyzed the data: DÖ GK KvL MR MW. Wrote the paper: DÖ GK KvL ME SvH MR MW.

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Fig 9. 9a: Funnel plot comparing complications in HALDN versus LDN. 9b. Funnel plot comparing complications in RDN versus LDN. 9c: Funnel plot comparing complications in HARDN versus LDN. 9d: Funnel plot comparing complications in LESS versus LDN. 9e: Funnel plot comparing complications in retroperitoneal versus transperitoneal approach. Studies at the bottom tend to cluster towards the right. 9f: Funnel plot comparing complications in hand-assisted versus fully laparoscopic approach.

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