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# Outcomes after totally minimally invasive *versus* hybrid and open Ivor Lewis oesophagectomy: results from the International Esodata Study Group

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## Abstract

**Background:** Large studies comparing totally minimally invasive oesophagectomy (TMIE) with laparoscopically assisted (hybrid) oesophagectomy are lacking. Although randomized trials have compared TMIE invasive with open oesophagectomy, daily clinical practice does not always resemble the results reported in such trials. The aim of the present study was to compare complications after totally minimally invasive, hybrid and open Ivor Lewis oesophagectomy in patients with oesophageal cancer.

**Methods:** The study was performed using data from the International Esodata Study Group registered between February 2015 and December 2019. The primary outcome was pneumonia, and secondary outcomes included the incidence and severity of anastomotic leakage, (major) complications, duration of hospital stay, escalation of care, and 90-day mortality. Data were analysed using multivariable multilevel models.

**Results:** Some 8640 patients were included between 2015 and 2019. Patients undergoing TMIE had a lower incidence of pneumonia than those having hybrid (10.9 *versus* 16.3 per cent; odds ratio (OR) 0.56, 95 per cent c.i. 0.40 to 0.80) or open (10.9 *versus* 17.4 per cent; OR 0.60, 0.42 to 0.84) oesophagectomy, and had a shorter hospital stay (median 10 (i.q.r. 8–16) days *versus* 14 (11–19) days ($P = 0.041$) and 11 (9–16) days ($P = 0.027$) respectively). The rate of anastomotic leakage was higher after TMIE than hybrid (15.1 *versus* 10.7 per cent; OR 1.47, 1.01 to 2.13) or open (15.1 *versus* 7.3 per cent; OR 1.73, 1.26 to 2.38) procedures.

**Conclusion:** Compared with hybrid and open Ivor Lewis oesophagectomy, TMIE resulted in a lower pneumonia rate, a shorter duration of hospital stay, but higher anastomotic leakage rates. Therefore, no clear advantage was seen for either TMIE, hybrid or open Ivor Lewis oesophagectomy when performed in daily clinical practice.

## Introduction

Neoadjuvant therapy plus oesophagectomy is the cornerstone of potentially curative treatment for patients with oesophageal cancer[1–4]. An oesophagectomy, however, is associated with substantial morbidity, mortality, and lasting symptoms, with reduced health-related quality of life[5–7]. Furthermore, it is known that postoperative complications might have detrimental prognostic consequences[8–11]. To reduce the risk of postoperative complications, a variety of minimally invasive surgical techniques have evolved over time[12]. Totally minimally invasive oesophagectomy (TMIE) resulted in short-term benefits (such as fewer in-hospital pulmonary infections, less pain, and less intraoperative blood loss) compared with open oesophagectomy in two RCTs using the McKeown technique[13,14]. In a population-based setting, TMIE was associated with an increase in rates of reoperation, major complications, and pulmonary complications[15,16]. A recent report[17] has shown show that an intrathoracic anastomosis performed using minimally invasive techniques has a long proficiency gain curve and high leak rates during the learning curve phases. This may explain why daily clinical practice does not resemble the complication rate reported in the randomized setting.

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A hybrid minimally invasive approach, in which an open thoracic phase (thoracotomy) is combined with a minimally invasive abdominal phase (laparoscopy), was compared with open oesophagectomy in the MIRO trial[18]. Use of hybrid oesophagectomy resulted in a decrease in major complications, specifically major pulmonary complications. Thus, both McKeown TMIE and Ivor Lewis hybrid oesophagectomy seem to have advantages over open oesophagectomy, particularly related to the incidence of pneumonia and/or pulmonary complications[13,14,18]. In the hybrid Ivor Lewis approach, the intrathoracic anastomosis is performed via a thoracotomy, and as such it can be hypothesized that there may be a lower anastomotic leakage rate than is associated with totally minimally invasive Ivor Lewis oesophagectomy. However, the thoracotomy could result in more pulmonary complications (such as pneumonia) than occur after thoracoscopy.

The International Esodata Study Group (IESG), which consists of high-volume oesophagectomy centres, previously reached consensus on definitions of complications after oesophagectomy[19,20]. All participating centres now register complications after oesophagectomy according to the definitions and standards of the IESG. The primary aim of the present study was to compare the incidence of postoperative pneumonia between TMIE, hybrid, and open Ivor Lewis oesophagectomy using data from the IESG. An additional aim was to assess and compare the rate and severity of anastomotic leakage, the rate of (major) complications, duration of hospital stay, rate of escalation of care, readmission rate within 30 days, and 90-day mortality.

# Methods

## Esophagectomy Complications Consensus Group database

This international cohort study was undertaken using data from the Esophagectomy Complications Consensus Group (ECCG) database. This database was developed by all contributing centres who are part of the IESG. Outcomes were reported according to the STROBE reporting guidelines for reporting observational research[21]. The IESG currently consists of 61 high-volume centres from 21 countries. All centres had previously signed an agreement to meet all requirements of the institutional ethics committee to supply anonymized patient information to the database. The publications and audit subcommittee of the International Society for Diseases of the Esophagus research and database committee approved the present study and supplied all of the original data required for it.

Complications after oesophagectomy were reported in a standardized manner and uniformly through web-based data retrieval forms. Complications were registered according to the uniform definitions of the ECCG[19]. All complications occurring within 30 days of surgery or during postoperative hospital stay were reported.

## Patients

Patients registered between February 2015 and December 2019 were included in this study. Only those who underwent potentially curative oesophagectomy using the Ivor Lewis approach (abdominal, open/laparoscopic approach and right-sided thoracotomy/thoracoscopy with intrathoracic anastomosis) were included. Patients who had palliative or transhiatal oesophagectomy, those who underwent definitive chemo(radio)-therapy, patients who underwent hybrid oesophagectomy consisting of laparotomy and thoracoscopy, those who had an oesophageal conduit other than stomach, and patients who had a neck anastomosis were excluded from further analysis. Three separate groups were defined based on the procedure: TMIE via laparoscopy and thoracoscopy; laparoscopically assisted oesophagectomy via laparoscopy and thoracotomy (hybrid); and open oesophagectomy via laparotomy and thoracotomy.

## Outcomes

The primary outcome of the present study was pneumonia, defined as new 'lung infiltrates plus clinical evidence that the infiltrate is of an infectious origin, which include the new onset of fever, purulent sputum, leucocytosis, and decline in oxygenation', according to the definition of the American Thoracic Society, the Infectious Diseases Society of America, and as used uniformly by the IESG in previous ECCG publications[19,22,23].

Secondary outcomes were the rate and severity of anastomotic leakage, rate of complications and rate of major complications, duration of hospital stay, rate of escalation of care (transfer of patient to higher level of care, such as from ward to ICU), readmission rate within 30 days after hospital discharge, and 90-day mortality. Finally, an overview was undertaken of all postoperative complications that are uniformly registered in the ECCG database.

Anastomotic leakage was defined as 'a full thickness gastrointestinal defect involving the esophagus, anastomosis, staple line or conduit irrespective of presentation or method of identification', according to the ECCG definitions[19]. The severity of anastomotic leakage was categorized into three types[19]: type I, a local defect without needing to change treatment, or treated medically or with dietary modification; type II, a local defect requiring non-surgical intervention (such as percutaneous drainage, stent placement or packing of incision); and type III, a local defect requiring surgical therapy. Major complications were defined as any postoperative complication graded at least IIIb according to the Clavien–Dindo classification, requiring an intervention under general anaesthesia[24].

## Statistical analysis

Continuous variables are presented as median (i.q.r.) and categorical data as frequencies with percentages. To assess the influence of surgical approach on postoperative complications, logistic multilevel model analysis was used for categorical outcomes and linear multilevel model analysis for linear outcomes. A hospital-specific random intercept and a hospital-specific random slope for surgical approach were used in the models to adjust for interhospital variability for all outcomes. Furthermore, adjustments were made for fixed effects, including sex, age, WHO performance status, clinical T category, clinical N category, tumour location, preoperative treatment, and tumour histology. Associations are presented as adjusted odds ratios for categorical outcomes, and standardized coefficients for linear outcomes, all with corresponding 95 per cent confidence intervals.

The variance of the multilevel models, which encompasses how much of the variance in outcomes can be explained by the variability of interhospital differences, was assessed. The variance in a model measures the average spread of each value from the mean. According to the latent variable method, the variance is divided by the variance plus a constant quantity ($\pi^2/3 = 3.29$). Therefore, a variance of, for example, 0.32 means that 8.9 per cent ($0.32/(0.32 + 3.29)$) of the variation in the outcome is attributable to differences between hospitals[25]. The larger this value, the more the variance can be explained by interhospital differences. The outcomes were adjusted for such interhospital differences in the multilevel models. Incomplete cases are efficiently handled

by multilevel model analysis[26]. All tests were two-sided and $P < 0.050$ was considered statistically significant. All statistical analyses were undertaken in R version 3.6.2 (R Core Team, R Foundation for Statistical Computing, Boston, MA, USA) using the lme4 package.

## Results

During the study interval, the IESG registered 8640 patients who underwent oesophagectomy in 39 hospitals from 20 countries. Of these, 4733 patients fulfilled the study requirements: 1472 patients underwent TMIE, 1364 hybrid oesophagectomy, and 1897 open Ivor Lewis oesophagectomy (*Fig. 1*). Baseline characteristics of the included patients are shown in *Table 1*.

### Interhospital variability

Participating centres carried out a median of 181 (i.q.r. 120–325) procedures during the study interval. TMIE was performed in 31 hospitals, hybrid oesophagectomy in 31, and open oesophagectomy in 36 hospitals. The number of TMIE procedures undertaken during the study interval ranged from 3 to 367, with median of 46 (30–129) per hospital; 25 hospitals undertook 20 or more TMIE procedures. For hybrid oesophagectomy, the number of procedures ranged from 1 to 599, with a median of 16 (3–49) per hospital; 15 hospitals performed at least 20 hybrid procedures. *Figure S1* summarizes the variance for all outcomes, explaining how much of the variability in results after each surgical approach is explained by interhospital variability. The rates of postoperative complications for each group are summarized in *Table 2*, and relevant comparisons are shown in *Table 3*. *Table S4* summarizes the univariable analyses of all comparisons.

### TMIE *versus* hybrid Ivor Lewis oesophagectomy

The pneumonia rate was lower among patients who had TMIE, and this group had a shorter hospital stay than those who underwent hybrid oesophagectomy (*Tables 2* and *3*). The anastomotic leakage rate was higher for TMIE than hybrid oesophagectomy. The severity of anastomotic leakage, rate of any complications, rate of major complications, rate of escalation of care, readmission rate within 30 days, and 90-day mortality rate were comparable in these two groups.

### TMIE *versus* open Ivor Lewis oesophagectomy

The pneumonia rate was lower for patients who underwent TMIE and the hospital stay shorter than for those who had open oesophagectomy. The anastomotic leakage rate was higher for patients undergoing TMIE. Other outcomes were comparable between the two groups (*Tables 2* and *3*).

### Hybrid *versus* open Ivor Lewis oesophagectomy

The rates of pneumonia and anastomotic leakage were similar for hybrid and open Ivor Lewis oesophagectomy. All other outcomes were comparable, with no significant differences (*Tables 2* and *3*).

### Pathological outcomes

The incidence of pathological outcomes is summarized in *Table 4*. Patients undergoing TMIE had a microscopically radical resection rate (R0) of 93.8 per cent compared with 93.2 per cent for hybrid oesophagectomy and 89.2 per cent for open oesophagectomy, with no significant differences between groups.

The median number of resected lymph nodes in TMIE was comparable to that for the other procedures (*Table 4*). This was also the case when hybrid was compared with open oesophagectomy (standardized coefficient –1.18, $P = 0.091$). The numbers of positive resected lymph nodes were also comparable between the three surgical techniques.

*Tables S1–S3* summarize all postoperative complications registered in the ECCG database.

## Discussion

This study investigated the incidence of postoperative complications after TMIE, hybrid, and open Ivor Lewis oesophagectomy using data from the IESG. Patients undergoing TMIE had a lower pneumonia rate and shorter hospital stay than those treated using hybrid or open approaches. The rate of anastomotic leakage, however, was significantly higher in patients undergoing TMIE.

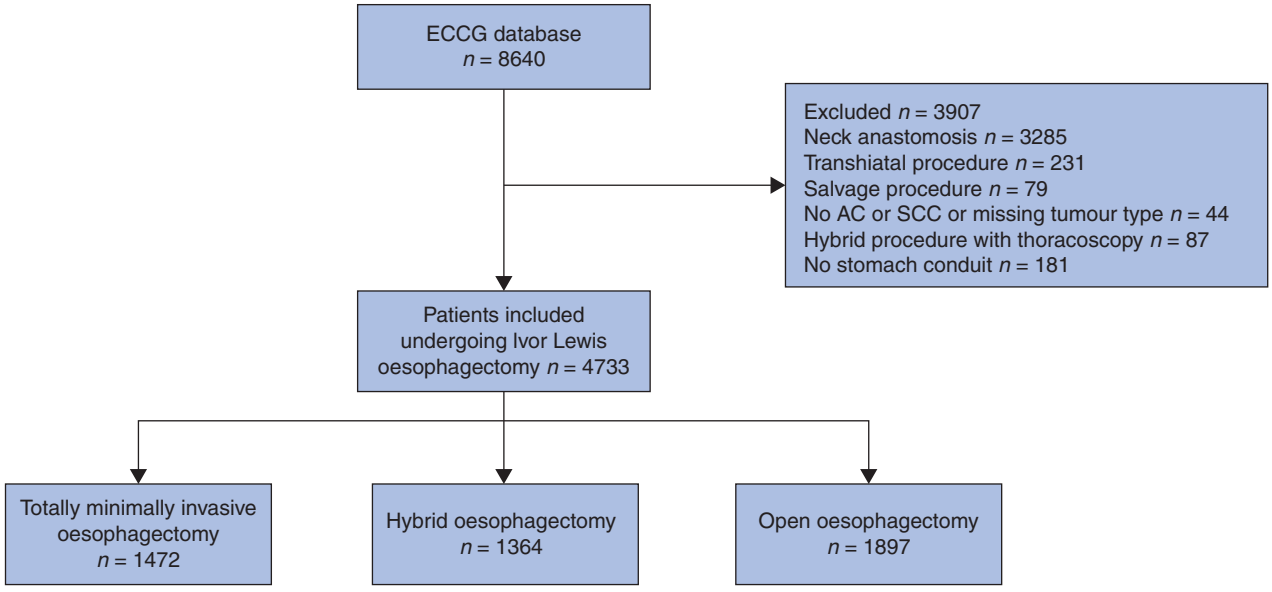


**Fig. 1** Study flow diagram showing included patients who underwent Ivor Lewis oesophagectomy

**Table 1 Basic characteristics of patients undergoing totally minimally invasive, hybrid or open Ivor Lewis oesophagectomy**

| | TMIE ($n = 1472$) | Hybrid† ($n = 1364$) | Open ($n = 1897$) |
|---|---|---|---|
| **Age (years)*** | 65 (58–71) | 64 (57–71) | 65 (58–71) |
| **Women** | 269 (18) | 241 (18) | 332 (18) |
| **Co-morbidities present** | 920 (63) | 1183 (87) | 1468 (77) |
| **WHO performance status** | | | |
| 0 | 841 (57) | 617 (45) | 1029 (54) |
| 1 | 580 (39) | 571 (42) | 798 (42) |
| 2 | 48 (3.3) | 130 (9.5) | 60 (3) |
| 3 | 3 (<1) | 45 (3.3) | 10 (<1) |
| 4 | 0 (0) | 1 (<1) | 0 (0) |
| **ASA fitness grade** | | | |
| I | 145 (9.9) | 118 (8.7) | 158 (8) |
| II | 667 (45) | 758 (56) | 875 (46) |
| III | 632 (43) | 487 (36) | 860 (45) |
| IV | 28 (1.9) | 1 (<1) | 3 (<1) |
| V | 0 (0) | 0 (0) | 1 (<1) |
| **Tumour location** | | | |
| Proximal 1/2 of esophagus | 41 (2.8) | 81 (5.9) | 68 (4) |
| Distal 1/2 of esophagus | 852 (58) | 757 (56) | 863 (46) |
| GOJ | 558 (38) | 505 (37) | 920 (49) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2) |
| **Histology** | | | |
| Adenocarcinoma | 895 (61) | 732 (54) | 1072 (57) |
| Squamous cell carcinoma | 146 (9.9) | 134 (9.8) | 191 (10) |
| Adenosquamous cell carcinoma | 6 (<1) | 3 (<1) | 9 (<1) |
| Missing | 425 (29) | 495 (36) | 625 (33) |
| **Clinical T category‡** | | | |
| cT0 | 4 (<1) | 5 (<1) | 3 (<1) |
| cTis | 7 (<1) | 4 (<1) | 15 (<1) |
| cT1 | 139 (9.4) | 91 (6.7) | 131 (7) |
| cT2 | 258 (18) | 166 (12) | 278 (15) |
| cT3 | 944 (64) | 1043 (77) | 1302 (69) |
| cT4 | 77 (5.2) | 26 (1.9) | 90 (5) |
| cTx | 22 (1.5) | 8 (<1) | 32 (2) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2) |
| **Clinical N category‡** | | | |
| cN0 | 544 (37) | 236 (17) | 728 (38) |
| cN1 | 554 (38) | 403 (30) | 690 (36) |
| cN2 | 226 (15) | 100 (7.3) | 284 (15) |
| cN3 | 32 (2.2) | 11 (<1) | 61 (3) |
| cNx | 95 (6.5) | 593 (44) | 88 (5) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2) |
| **Preoperative treatment** | | | |
| None | 265 (18) | 234 (17) | 354 (19) |
| Chemoradiotherapy | 973 (66) | 683 (50) | 765 (40) |
| Chemotherapy | 212 (14) | 424 (31) | 731 (39) |
| Radiotherapy | 1 (<1) | 2 (<1) | 1 (<1) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2.4) |

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.). †Laparoscopically assisted oesophagectomy (laparoscopy and thoracotomy). ‡ Clinical Tumor and Nodal stage. TMIE, totally minimally invasive oesophagectomy; GOJ, gastro-oesophageal junction.

**Table 2 Incidence of postoperative complications and duration of hospital stay in patients undergoing totally minimally invasive, hybrid or open Ivor Lewis oesophagectomy**

| | TMIE ($n = 1472$) | Hybrid ($n = 1364$) | Open ($n = 1897$) |
|---|---|---|---|
| **Pneumonia** | 160 (10.9) | 222 (16.3) | 331 (17.4) |
| **Anastomotic leakage** | 222 (15.1) | 146 (10.7) | 139 (7.3) |
| Type I | 39 (2.6) | 19 (1.4) | 51 (2.7) |
| Type II | 113 (7.7) | 79 (5.8) | 51 (2.7) |
| Type III | 70 (4.8) | 48 (3.5) | 37 (1.9) |
| **Complications** | | | |
| Any | 881 (59.9) | 855 (62.7) | 1100 (58.0) |
| Major (CD ≥ IIIb) | 283 (19.2) | 219 (16.1) | 298 (15.7) |
| **Escalation of care** | 183 (12.4) | 198 (14.5) | 516 (27.2) |
| **Readmission within 30 days** | 191 (13.0) | 81 (5.9) | 184 (9.7) |
| **Duration of hospital stay (days)*** | 10 (8–16) | 14 (11–19) | 11 (9–16) |
| **90-day mortality** | 65 (4.4) | 46 (3.4) | 75 (4.0) |

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.). TMIE, totally minimally invasive oesophagectomy; CD, Clavien–Dindo.

No differences were reported between hybrid or open Ivor Lewis approaches.

A recently published meta-analysis[27] of non-randomized studies compared TMIE with hybrid oesophagectomy. Four studies were pooled that reported on the incidence of pneumonia, including 297 patients in total. The authors did not report a higher incidence of pneumonia for hybrid oesophagectomy compared with TMIE. However, there was heterogeneity in the definitions of pneumonia between the studies. The present study, which used a uniform definition of pneumonia from the ECCG and compared over 2800 patients undergoing TMIE or hybrid Ivor Lewis oesophagectomy, reported a statistically significant difference in pneumonia rate favouring TMIE over hybrid and open Ivor Lewis oesophagectomy. This higher rate for laparoscopically assisted hybrid and open oesophagectomy most probably reflects the more invasive thoracic procedure as both required a thoracotomy. The present results confirmed the findings of the randomized TIME[13] and ROBOT[14] trials, which compared TMIE or robotically-assisted minimally invasive oesophagectomy with open oesophagectomy, and showed a decrease in the rate of pneumonia and pulmonary complications. However, in the present study, there was no difference in pneumonia rate between open and hybrid oesophagectomy, even though the approaches compared were the same as those in the MIRO trial, which randomized and compared patients undergoing either a hybrid (laparoscopy and open thoracotomy) or open oesophagectomy. That trial[18] reported a significant decrease in major pulmonary complications for hybrid oesophagectomy, defined as pulmonary complications of at least Clavien–Dindo grade II. The pneumonia rates, however, were not analysed separately. In the database used for the present study, the severity of postoperative complications according to the Clavien–Dindo classification was not specified for each complication, making it difficult to make direct comparisons with that study.

In the present study, a higher anastomotic leakage rate was reported for TMIE than hybrid oesophagectomy. The meta-analysis[27] that compared TMIE with hybrid oesophagectomy reported a significant increase in anastomotic leakage rate for TMIE compared with hybrid Ivor Lewis oesophagectomy. This was most probably due to the technically challenging minimally invasive intrathoracic anastomosis. Hypothetically, the increase in anastomotic leakage rate for TMIE in the present study reflects a proficiency gain curve in centres during implementation of this new technique, as collection of data took place while TMIE was being implemented. If so, it can be expected that anastomotic leakage rates will drop after more patients have been treated[17]. However, after adjustment for interhospital variability, the increased anastomotic leakage rate remained for TMIE. Furthermore, hospitals that undertook most TMIE procedures did not have the lowest anastomotic leakage rates *per se*, which is partly reflected by the estimated rate of variability which can be explained by interhospital differences. Finally, it is remarkable that, despite a decrease in pneumonia, the anastomotic leakage rate for TMIE was higher even though these complications often coincide.

**Table 3 Multilevel models comparing postoperative complications after totally minimally invasive, hybrid or open Ivor Lewis oesophagectomy**

| | TMIE *versus* hybrid† | | TMIE *versus* open† | | Open *versus* hybrid† | |
|---|---|---|---|---|---|---|
| | Adjusted OR | *P* | Adjusted OR | *P* | Adjusted OR | *P* |
| **Pneumonia** | 0.56 (0.40, 0.80) | 0.001 | 0.60 (0.42, 0.84) | 0.003 | 0.99 (0.74, 1.32) | 0.948 |
| **Anastomotic leakage** | | | | | | |
| Rate | 1.47 (1.01, 2.13) | 0.045 | 1.73 (1.26, 2.38) | < 0.001 | 0.79 (0.52, 1.20) | 0.267 |
| Severity (type I–II *versus* III) | 0.57 (0.27, 1.18) | 0.131 | 0.95 (0.46, 1.96) | 0.886 | 0.61 (0.29, 1.27) | 0.188 |
| **Complications** | | | | | | |
| Any | 0.89 (0.68, 1.17) | 0.404 | 0.82 (0.59, 1.14) | 0.239 | 1.03 (0.74, 1.43) | 0.874 |
| Major (CD ≥ IIIb) | 1.17 (0.83, 1.65) | 0.365 | 1.25 (0.95, 1.65) | 0.116 | 0.91 (0.59, 1.41) | 0.684 |
| **Escalation of care** | 0.89 (0.63, 1.26) | 0.505 | 0.62 (0.36, 1.07) | 0.09 | 1.39 (0.81, 2.36) | 0.229 |
| **Readmission within 30 days** | 0.97 (0.48, 1.97) | 0.940 | 1.16 (0.73, 1.86) | 0.534 | 0.73 (0.39, 1.37) | 0.329 |
| **Duration of hospital stay** | −2.6 (−5.0, −0.24)* | 0.041 | −2.2 (−3.8, −0.5)* | 0.027 | −0.3 (−2.8, 2.0)* | 0.779 |
| **90-day mortality** | 1.01 (0.51, 2.01) | 0.978 | 0.83 (0.47, 1.44) | 0.497 | 1.65 (0.80, 3.40) | 0.179 |

Values in parentheses are 95 per cent confidence intervals; *Standardized coefficients. †Reference group. TMIE, totally minimally invasive oesophagectomy; OR, odds ratio; CD, Clavien–Dindo. Analyses were adjusted for random hospital effects, tumour histology, preoperative treatment, age, sex, WHO performance stats, cT category, cN category, and tumour location.

**Table 4 Pathological outcomes after totally minimally invasive, hybrid or open Ivor Lewis oesophagectomy**

| | TMIE (*n* = 1472) | Hybrid (*n* = 1364) | Open (*n* = 1897) |
|---|---|---|---|
| **Pathological T category** | | | |
| pT0 | 280 (19.0) | 239 (17.5) | 253 (13.3) |
| pTis | 11 (0.7) | 2 (0.1) | 9 (0.5) |
| pT1 | 324 (22.0) | 282 (20.7) | 345 (18.2) |
| pT2 | 227 (15.4) | 197 (14.4) | 269 (14.2) |
| pT3 | 569 (38.7) | 577 (42.3) | 875 (46.1) |
| pT4 | 33 (2.2) | 36 (2.6) | 91 (4.8) |
| pTx | 7 (0.5) | 2 (0.1) | 9 (0.5) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2.4) |
| **Pathological N category** | | | |
| pN0 | 855 (58.1) | 743 (54.5) | 953 (50.2) |
| pN1 | 310 (21.1) | 305 (22.4) | 449 (23.7) |
| pN2 | 187 (12.7) | 165 (12.1) | 253 (13.3) |
| pN3 | 98 (6.7) | 128 (9.4) | 195 (10.3) |
| pNx | 1 (0.1) | 2 (0.1) | 1 (0.1) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2.4) |
| **Pathological M category** | | | |
| pM0 | 1363 (92.6) | 1254 (91.9) | 1592 (83.9) |
| pM1 | 13 (0.9) | 25 (1.8) | 46 (2.4) |
| pMx | 75 (5.1) | 64 (4.7) | 213 (11.2) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2.4) |
| **Radicality of resection** | | | |
| R0 | 1381 (93.8) | 1271 (93.2) | 1693 (89.2) |
| R1 | 70 (4.8) | 70 (5.1) | 152 (8.0) |
| R2 | 0 (0) | 2 (0.1) | 6 (0.3) |
| Missing | 21 (1.4) | 21 (1.5) | 46 (2.4) |
| **No. of resected lymph nodes*** | 30 (21–40) | 29 (22–37) | 26 (19–34) |
| **No. of lymph nodes containing tumour cells*** | 0 (0–2) | 0 (0–2) | 0 (0–2) |

Values in parentheses are percentages unless indicated otherwise; *values are median (i.q.r.). TMIE, totally minimally invasive oesophagectomy.

A previous meta-analysis[8] reported a decrease in overall survival after development of anastomotic leakage or pneumonia in patients undergoing any type of oesophagectomy. Furthermore, in a study[10] that included only patients undergoing TMIE, anastomotic leakage resulted in decreased long-term survival compared with that among patients who did not develop anastomotic leakage. In the present study, the 90-day postoperative mortality rate was, however, comparable between the groups. The only way to definitively assess the importance of differences in postoperative complications is to prospectively and directly compare both surgical techniques, powered on outcomes such as overall survival and long-term postoperative health-related quality of life.

To the authors' knowledge, this is the largest study comparing postoperative outcomes after different approaches to Ivor Lewis oesophagectomy for oesophageal cancer. The IESG[19,20] previously reached an international consensus on standardized reporting of the most important postoperative complications. This resulted in a robust and standardized comparison between surgical approaches used throughout the world.

The present study has some limitations. Healthcare personnel were not blinded to the procedure performed. The duration of hospital stay could have been influenced by surgical approach as known to the healthcare provider in the surgical ward. Some variables that would be of value in the present study were not reported in the database. The anastomotic technique used (end to side, side to side, circular or linear stapled) in oesophagectomy has been associated with the risk of anastomotic leakage[28]. These anastomotic techniques were not registered in the database and could not therefore be adjusted for. Other variables of interest but not reported in the database are the rate of surgical conversion and survival after different surgical techniques. Although adjustment was made for interhospital differences, international outcomes for oesophagectomy remain variable and can still lead to variability in comparison[29,30]. Finally, although the definition of pneumonia was highly standardized, there was no clear definition developed specifically for postoperative pneumonia. A standardized severity score should be reported for pneumonia to gain insight into its possible impact in the postoperative setting. To the best of the authors' knowledge, the only randomized trial including both laparoscopically assisted hybrid oesophagectomy and TMIE (both McKeown and Ivor Lewis) is the ROMIO trial[31]. This ongoing trial, however, is randomizing only a small number of patients to the TMIE group by means of a substudy with the aim of evaluating the safety of TMIE. Overall survival and postoperative complications will therefore probably not be evaluated with sufficient power to find an improved outcome for either surgical technique.

This study has shown no clear advantage for either TMIE, hybrid or open Ivor Lewis oesophagectomy when performed in daily clinical practice, and the choice of surgical approach should depend on centre experience, centre volume, and surgeon preferences. Minimally invasive techniques should be further developed

to minimize postoperative complications, such as anastomotic leakage.

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## Supplementary material

Supplementary material is available at *BJS* online.

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