Review Article

Uniportal video-assisted thoracoscopic pulmonary segmentectomy: a systematic review

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Abstract: Sublobar resection for early stage lung cancers and for preinvasive lung lesions is gaining popularity. Open and minimally invasive approaches have been well established in this procedure. Uniportal thoracic surgery, of late has been quite widely accepted, used across the globe due to its advantages. Data available to support this is limited and is in the form of small series. This article provides a comprehensive review of scientific literature in English language on uniportal video-assisted thoracoscopic surgery (VATS) segmentectomy. It was found that uniportal segmentectomy is feasible and safe with acceptable rates of postoperative complications and mortality rates (30-day mortality). Studies comparing uniport with multiport segmentectomy have shown former to be associated with shorter postoperative hospital stay and shorter duration of intercostals drainage. and are comparable in terms of nodal yield and duration of surgery. Histopathological analysis in most of the studies reveal the patients to have early stage tumours, with many having preinvasive and micro invasive tumours. The literature available supports the use of uniportal segmentectomy in select patients with early stage lung cancer. The oncological safety and efficacy can be determined only on long-term follow-up analysis of survival and recurrence patterns.

Keywords: Uniportal video-assisted thoracoscopic surgery segmentectomy (uniportal VATS segmentectomy); single port thoracoscopy surgery; pulmonary segmentectomy; lung cancer surgery

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Introduction

Lung cancer management has witnessed major changes in the last decade, especially in the form of minimally invasive approaches and robotic surgery. One such significant development is the uniportal video-assisted thoracoscopic surgery (VATS). Along with an increased interest in minimalistic approach, there has been a recent rise in the interest towards conservative approaches, especially for early stage lung cancers. The initial trial of lobectomy *vs.* sublobar resections (1) conducted more than decades before, now stands outdated and obsolete, given the advancement in radiological advancement in the form of better imaging facilities, which pick up more and more early lesions. Also the recent published set of data though retrospective in nature, on use of sublobar resections for early stage lung cancer, support the use of sublobar resections especially segmentectomy (in select cases) (2). Newer trials are at present evaluating the validity of sublobar resection in the

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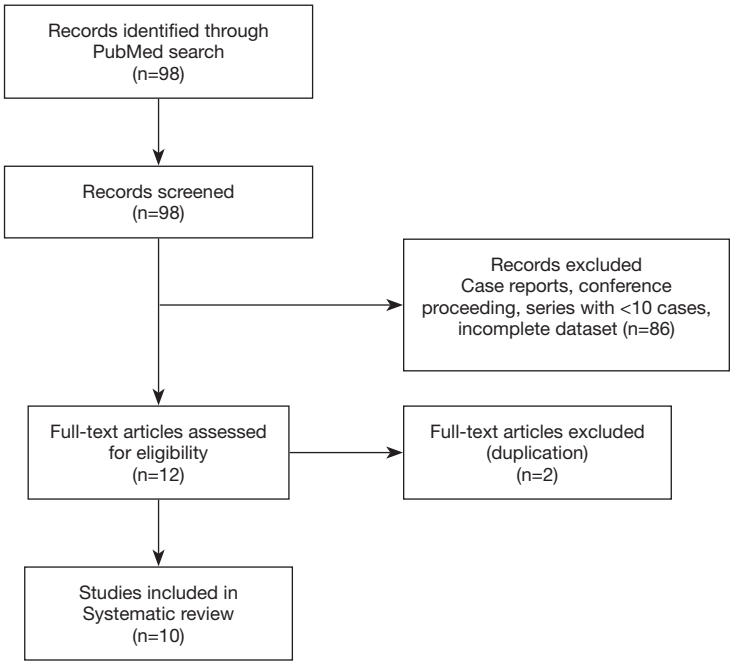

Figure 1 PRISMA flow diagram.

present scenario (3).

Segmentectomy is a demanding procedure, requires a very good knowledge of anatomy, the vessels and its branches with bronchial divisions to help target the necessary portion of lung with minimal damage to the rest of the parenchyma. Segmentectomy by uniportal technique is further demanding, combining the advantages of both minimally invasive and conservative approach.

There have been only few centres in the world which routinely practice uniportal segmentectomy and only a few articles have been published in detail. Most of the publications have been case reports describing the technique of a particular segmentectomy. There is a lack of large volume published data on uniportal segmentectomy. In this review article we look into the literature available as on date, in the indexed journals, describing uniportal segmentectomy. We are not discussing the techniques of segmentectomy which are discussed in another publication from our centre (4).

Methods

Electronic search was performed in PubMed for the terms "Uniportal segmentectomy", "Single port Thoracoscopic Segmentectomy" on 12.8.2019. After initial review, relevant full text articles were retrieved. Eligible studies included all original articles and case series publications, which described the results of uniportal segmentectomy of lung. Case reports, editorial publications, conference proceedings in the form of abstracts, expert opinions were excluded from analysis. Case series describing <10 cases were excluded from the analysis. Studies describing combinations of segmentectomy with other resections (lobectomy/wedge), without separate data on uniportal segmentectomy were also excluded from the analysis (PRISMA diagram, *Figure 1*).

Data from the publications were retrieved, reviewed and analysed independently by the two authors (B Venkitaraman and L Jiang). Any disparities in the observations between the two observes were discussed and resolved and the final consensus is presented here. Statistical analysis was done using SPSS Statistics for windows version 17.0 (SPSS Inc., Chicago, USA).

Results

A total of 98 articles were identified on initial search. After initial review, and removal of case reports and articles with incomplete dataset, 12 articles were found to satisfy the inclusion criteria for this review and were further analysed. Two were removed for possible repetition of cases. All the studies included were non randomised studies from single surgical centre, reporting their experience in the uniportal

Table 1 Summary of studies on uniportal segmental resections

Authors	Publication year	Study period	Procedure performed	Uniportal (numbers)	Multiport (numbers)
Ali *et al.* (4)	2018	Sep 2014–Apr 2017	Sub xiphoid segmentectomy	242	0
Cheng *et al.* (5)	2016	May 2014–Jul 2016	Uniportal segmentectomy	40	0
Lee *et al.* (6)	2019	Aug 2010–Aug 2018	Uniportal *vs*. multiport segmentectomy	33	51
Han *et al.* (7)	2016	Mar 2006–Oct 2015	Uniportal *vs*. multiport segmentectomy	34	11
Yang *et al.* (8)	2017	Dec 2016–Jun 2017	Needlescopic assisted uniportal segmentectomy	22	0
Xu *et al.* (9)	2019	Jul 2017–Nov 2018	3D imaging associated uniportal segmentectomy	133	0
Shih *et al.* (10)	2016	May 2006–Mar 2014	Multi-port *vs*. single-port segmentectomy	52	46
Lin *et al.* (11)	2016	Apr 2014–Jun 2015	Single port VATS segmentectomy	32	0
Huang *et al.* (12)	2018	May 2014–Dec 2016	Single port VATS segmentectomy	45	0
Duan *et al.* (13)	2018	2015–2016	Uniportal segmentectomy	156	0

segmentectomy. Of the 10 studies three were comparative studies, comparing uniportal with multiport VATS segmentectomy while the rest evaluated only uniportal series (*Table 1*).

Indications

The most important part of surgical management is the selection of right cases. Various studies have described different selection criteria for patients undergoing uniportal VATS segmentectomy. The consistent features among these include:

- Benign or suspected benign lesion, where wedge is not feasible;
- Inflammatory lesions where segmentectomy can offer preservation of lung parenchyma;
- Metastatic lesions to lung not amenable to wedge resection;
- Ground glass lesions with solid component <50%, bilateral lesions;
- For patients with early stage lung cancer especially for tumour size <2 cm;
- Segmentectomy may be done in select patients who will not be fit for lobectomy due to their pulmonary compromise.
    - Of late more and more patients with lesions <2 cm in peripherally placed lesions with no nodes have undergone segmentectomy especially if margin of 2 cm at least can be achieved after segmentectomy (4,5,7,13).

Routine contraindications include presence of dense adhesions, where visualisation of anatomy is difficult. The same also depends on the expertise of the surgeon and his team.

Presence of visceral pleural invasion is still an unclear entity and use of segmentectomy in these patients may be guardedly used. Presence of positive nodes has also been considered as an indication for completion lobectomy in patients with non-small cell lung cancer.

Learning curve

Minimally invasive procedures, need a longer time for reaching the plateau of learning curve. segmentectomy is a technically demanding procedure and performance by uniportal adds to the complexity. Among the published literature, few have analysed their outcomes over the years of experience and it was found that with performance of close to 33 procedures, surgeons reached the plateau of learning curve (5). Duan *et al*. also found that operative time, blood loss and localisation rates were significantly lower with increase in the experience in their study (13).

Techniques of identification of intersegmental plane

The important aspect of segmentectomy is the identification of the intersegmental plane, so that appropriate parenchymal division can be made. There have been different techniques described (7). The inflation deflation technique has been

the most commonly applied technique (7) for identification of the intersegmental plane for parenchyma resection. After inflation and an application of stapler to divide a segmental bronchus and deflation, the target parenchyma remains inflated, helping us define the boundaries for resection. The downside of using this procedure is that vision gets obscured in the process of lung inflation and also presence of any collaterals can alter the inflation/deflation and lead to incorrect extent of parenchymal division.

Han *et al*. used intra operative bronchoscopy along with the above described technique to confirm the choosing of right bronchial division before performing the segmentectomy (7). Other techniques described in literature include open inflation technique (4), where in a bronchotomy of the segmental bronchus to be resected is done and the segment parenchyma alone is inflated using a deep vein catheter to inflate the segmental parenchyma and to define the plane. Others include use of 3D reconstruction of the segmental anatomy preoperatively as described by Xu *et al*. They utilised the system of 3D reconstruction of CT images prior to surgery using IQQA-3D analysis system. They compared the application of the 3D reconstruction system to non-application in uniportal VATS segmentectomy. They identified 57.3% segmental structure variations applying the software, most of these were single structure variations (69.1%) and most were segmental artery variations. On comparing the two groups, they found that even complicated surgeries could be performed without increase in the intraoperative time using preoperative 3D reconstruction. Thus, 3D technique was useful in the easy conduct of segmentectomy. They also used inflation deflation technique for identification of intersegmental plane (9).

Localisation of tumour

Yang *et al*. described technique of needlescopic localisation of the tumour preoperatively (8). These helped in exact localisation of non-palpable lesions and help in targeted excision. Hook wire placement was also performed in the series by Duan *et al*. (13). These were placed within two cm of the suspected lesion, under CT scan guidance. However, in the series from Shanghai pulmonary hospital, the placement of guidewire was only done, when it was difficult to exactly localise the lesion to a particular anatomical segment. This helps in guided resection and also in guided pathological assessment at Frozen section analysis (4).

Preoperative patient parameters

The mean age of patients included in the study ranged from 52 to 71.06 years. Most of these studies were performed on elective segmentectomy, on patients who were otherwise fit. This is based on the published preoperative pulmonary function tests results, where preoperative FEV1% was found to be more than 70% (4,8-10,12). Preoperative comorbid illness was also described in few studies and ranged from 31.1% to 52.5%. Contrary to the studies from West, the smoking prevalence was significantly low—ranging from 12.5% in most studies, going up to 24.2% (4,6,8,9,11,13). Most of these patients were also non-obese with BMI of patients being around 24 (4,6,8). The details of preoperative patient condition are described in detail in the *Table 2*.

Operative parameters

All the surgeries were performed starting with uniportal VATS technique with a 4-cm incision on the chest wall and using special double-jointed instruments. The operative time ranged from 128 to 198 minutes in different series. Duan *et al*. in their analysis showed that the operative time and mean blood loss was significantly lesser in the latter part of the study (13). Cheng *et al*. analysed their patients in four temporal divisions and found similar outcomes, lowering of operative time and blood loss with increasing experience (5).

In the three studies which compared uniportal with conventional multiport segmentectomy, there was no significant difference between the two techniques with respect to the operative time (6,7,10). Lee *et al*. alone described a significant lower intraoperative blood loss with uniportal technique (6). Lee *et al*. described a conversion rate of 9% from uniportal to multiport technique, while Han *et al*. and Shih *et al*. described no multiport conversion. Conversion to open thoracotomy was in the range of 1.9–5.8% (6,7,10). Most common reason for conversion was dense adhesions obscuring the anatomy and intraoperative bleeding. There was no difference between the uniportal and multiport group in terms of conversion rates to thoracotomy (6). There were also few cases of conversion to lobectomy, because of inability to identify the lesion Intraoperatively (2.9–4.2%) (7,8). The comparative studies also revealed no significant difference in the number of nodes resected between the uniportal and conventional techniques of VATS segmentectomy (6,7,10). All these emphasise the fact that uniportal segmentectomy is as

Table 2 Preoperative patient's parameters

Authors	Age (years)	FEV_1%	Smoking	BMI (kg/m^2)	Comorbid illness
Ali *et al.*	56.77	93.78	12.55%	23.78±3.3	NA
Cheng *et al.*	53.7	NA	NA	NA	52.5%
Lee *et al.*	67.7	2.3±0.8#	24.2%	24.7±3.0	51.6%
Han *et al.*	60	NA	NA	NA	NA
Yang *et al.*	52	100.8±18.8	12.5%	24.4±3.3	NA
Xu *et al.*	51.85	95.3±14.8	12.5%	NA	NA
Shih *et al.*	61.7	80.15±7.4	NA	NA	NA
Lin *et al.*	53.5	NA	12.5%	NA	40.6%
Huang *et al.*	71.06*	85.51±2.44	NA	NA	31.1%
Duan *et al.*	53.5±12.7	73.6±31.4	23.7%	NA	42.9%

*, in the elderly age subgroup; #, in litres (FEV_1). NA, not available.

Table 3 Operative parameters

Authors	Operative time	Blood loss (mL)	Lymph node stations removed	Lymph nodes removed	Conversion to thoracotomy (%)	Conversion to lobectomy (%)
Ali *et al.*	2.14±0.78 h	93.33	4	10.64±3.3	1.65	1.23
Cheng *et al.*	174±51.5 min	81.9±57.4	5.5±1.6	13.1±7.0	0	0
Lee *et al.*	180 min	50	NA	5	3.0	0
Han *et al.*	148±65 min	NA	NA	14±6	5.8	2.9
Yang *et al.*	178.3±65.6 min	NA	NA	11.5	0	4.2
Xu *et al.*	171.5 min	44.3±18.2	NA	NA	NA	NA
Shih *et al.*	3.3±0.97 h	63.27±78.2	NA	19.2±10.7	0	0
Lin *et al.*	186.5±57 min	77.3±50.9	3.4±0.9	9.6±4.9	0	0
Huang *et al.*	211.93±17.4 min	94.67±18.6	5.6±0.35	15.4±2.6	NA	NA
Duan *et al.*	123±45 min	60±14	NA	6±2	1.9	0.6

NA, not available.

effective as multiport conventional VATS surgery.

The details of operative parameters observed in various studies are further in *Table 3*.

Postoperative outcome

Mean postoperative stay in the hospital among the various studies ranged from 4 to 7.4±1.9 days. The reported mean duration of intercostal drainage was between 2–5.9 days. In the comparative studies between uniportal and multiportal by Lee *et al*. and Han *et al*., the uniportal arm had a significantly lesser duration of chest tube drainage and postoperative stay compared to multiport arm, an important post-operative parameter in favour of uniportal surgery. There was no reported 30-day mortality in any of the studies. The postoperative complication rates varied from as low as 4.2% to as high as 21.2% in the studies included. The most common postoperative complications reported in the studies included prolonged air leak (6,7), arrhythmias (4), postoperative lung infections (11,12) (*Table 4*).

Table 4 Postoperative outcomes

Authors	Post-op drains duration (days)	Post op stay (days)	Mortality (30-day mortality)	Postoperative complications (%)
Ali *et al.*	4.5±2.6	4.67±9.54	0	8.26
Cheng *et al.*	5.9±2.5	4.6±1.5	0	4.2
Lee *et al.*	2	4	0	21.2
Han *et al.*	NA	5.5±4.1	0	35.2
Yang *et al.*	5.2±1.5	7.4±1.9	0	8.3
Xu *et al.*	NA	4.9±3.6	0	8.2
Shih *et al.*	NA	5.77±1.98	0	NA
Lin *et al.*	4.7±1.6	6.0±2.6	0	6.3
Huang *et al.*	5.0±0.74	5.04±1.3	0	13.3
Duan *et al.*	NA	4.2±1.6	0	8.3

Histopathological analysis

The postoperative Histopathological analysis was well documented in many of the studies. The majority of these studies had reported having preinvasive tumours (Adenocarcinoma *in situ*) and T1 (mi) (minimally invasive adenocarcinoma (as per the AJCC 8.0 edition staging system) in the final operative specimen. The presence of adenocarcinoma *in situ* ranged from 4.5% to as high as 39.1% (9,13). Ali *et al*. also reported a high percentage of AIS (36.36%) (4). Minimally invasive adenocarcinoma defined as adenocarcinoma (≤3 cm in greatest dimension) with a predominant lepidic pattern and ≤5 mm invasion in the greatest dimension in the recent AJCC 8.0 Classification and is staged as T1 (mi). This was reported as high as 71.4% and 84.37% in the studies (9,11). Invasive adenocarcinoma was found comparatively lesser in number ranging from 9.38% to 31.82% (4,11). Many studies had reported the histopathology report in terms of stage of tumour. The majority of the studies had stage 1 tumours (4,6,10-12). Most of the tumours were small in size with the mean size of the tumour ranging from 0.7 to 2.15 cm, most of them being less than 2 cm in dimension (*Table 5*).

These pathological reports further justify the use of segmentectomy in these patients, as majority of them were early stage lung cancers. In many of the studies a formal mediastinal nodal dissection was included as a part of the surgery, after an intraoperative frozen or in patients with preoperative diagnosis of lung cancer.

Limitations

A major limitation in all of these studies is the lack of reporting of long-term survival, among patients undergoing segmentectomy (sublobar resection) for lung cancer. None of these studies have reported a methodical follow up plan and none of them reported the time of recurrence and site of recurrences. The availability of this survival analysis and recurrence pattern analysis will help further favouring or refuting the use of segmentectomy for early stage lung cancers and will also help in modifying the treatment regimes.

Conclusions

In this review, the articles included show a low and acceptable rate of post-operative morbidity with no 30-day mortality for uniportal segmentectomy, suggesting that uniportal segmentectomy for early stage lung cancer is feasible and safe in terms of post-operative outcomes, in experienced centres. Most of the studies also report an acceptable level of lymph node dissection in the mediastinum and hilum, thus proving uniportal approach to segmentectomy to be oncologically sound. Most of these studies have included patients who have small tumours, majority with lesion size <2 cm. Adenocarcinoma *in situ* and minimally invasive adenocarcinoma (reclassifications of bronchoalveolar type lung cancer), have been reported more commonly compared to invasive adenocarcinoma in many

Table 5 Postoperative histopathological analysis

Authors	Invasive tumour	Minimally invasive adenocarcinoma	Adenocarcinoma *in situ*	Stage	Lesion size
Ali *et al.*	31.82%	20.66%	36.36%	Stage T1a	1.214 cm
Cheng *et al.*	NA	NA	NA	NA	NA
Lee *et al.*	NA	NA	NA	30.3% Ia1, 45.5% Ia2; IIB 6.1%, IIIA 6.1%	1.9±2.2 mm
Han *et al.*	51.1% (primary lung cancer)	NA	NA	NA	1.8±0.7 cm
Yang *et al.*	62.5% (adenocarcinoma)	NA	NA	NA	1.2±0.5 cm
Xu *et al.*	23.3%	71.4%	4.5%	NA	0.85±0.3 cm
Shih *et al.*	NA	NA	NA	Stage I: 80.85%; stage II: 12.77%; stage III: 9.09%	2.15±1.03 cm
Lin *et al.*	9.38%	84.37%	6.25%	All <T1a	7.3±2.4 mm
Huang *et al.*	31.1%	68.9%	NA	All stage 1a	0.81±0.06 cm
Duan *et al.*	18.5%	25%	39.1%	NA	1.2±0.4 cm

NA, not available.

of the studies. These have been reported to have very good survival rates after complete surgical removal. These values suggest that uniportal segmentectomy may be performed on patients with tumors <2 cm and in those suspected to have lesser invasive variants. In future long-term analysis of Survival and recurrence will further confirm the long-term utility of uniportal segmentectomy in early stage lung cancer patients.

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Footnote

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