Thoracoscopic procedures have been described since the first part of the 20th century (1), with successive technological advances facilitating the advent of contemporary minimally-invasive surgery (MIS). Video-assisted thoracic surgery (VATS) has been in routine clinical practice for the past 3 decades, with anatomical lung resection having been reported since the early 1990s (2,3), and with minimal serious adverse events (4,5).

Thoracic registry data from the Society for Cardiothoracic Surgery (SCTS) in the United Kingdom for the 2014 to 2015 period reports 2,303 of 5,883 (39.1%) lobectomies were performed by VATS: an increase of 10% over the previous year (http://scts.org). The European Society of Thoracic Surgeons (ESTS) database annual report in 2015, which condenses data from 222 thoracic surgery units from 24 countries from around the world, reports 22% of major lung resections were performed by VATS between 2011 and 2014—up from 4% between 2007 and 2010 (http://ests.org).

The popularisation of MIS, whilst remaining variable and limited in thoracic surgery, has been facilitated by sequential advances in imaging technology: including the advent of fixed and variable-angled scopes, and the adoption of two-dimensional (2D) high-definition (HD) systems.

This article presents the contemporary evidence on three-dimensional (3D) imaging systems in thoracic surgical operating theatres.

**Methodology**

A literature search was conducted for (3D or “three dimension”) and (VATS or “thoracic surgery” or thoracoscopy) in the Excerpta Medica database (EMBASE), Medical Literature Analysis and Retrieval System Online (MEDLINE) and Cochrane Central Register of Controlled Trials (CENTRAL) databases, with no time restriction. Backward snowballing was additionally adopted.

All study types were included, with no restrictions set as to subjects. Only literature published in English was reviewed and considered for inclusion.

Search results were filtered by title, and the selected abstracts reviewed. The full article text was subsequently analysed and considered for inclusion.

There was no attempt at mathematical analyses of the data reviewed, and no access was sought to original or yet
unpublished data.

Results

The search returned 271 results, with 15 articles being eligible for full text evaluation following a review of titles and abstracts; of which 8 were selected for final inclusion.

Dickhoff et al. report their initial experience emphasising the feasibility of using a flexible-tip camera with 3D technology in anatomic lung resection in four patients, with no intraoperative complications and an uneventful postoperative recovery (6).

A study in 18 patients with T1 non-small-cell lung cancer (NSCLC), randomised to undergo VATS lobectomy using 2D HD or 3D HD systems, were operated by a single surgeon. The 3D group had a shorter operative time (146 vs. 177 minutes, P<0.001), with no complications noted, equivocal lymph node dissection, and no difference in intraoperative blood loss, or postoperative recovery (7).

Data for 300 patients from two-institutions in China, randomised to either 3D or 2D VATS lobectomy, similarly notes a reduction in operative time (145 vs. 176 minutes, P=0.006), with no difference in intraoperative or in-hospital postoperative outcomes. Direct comparison similarly found no difference for in-hospital costs between the two groups (11,487 vs. 11,388, P=0.913) (8).

Similar evidence for shorter operative time as the only difference noted with the introduction of 3D VATS lobectomy, emerges from single-institution retrospective data from 359 (9) and 278 patients (10) respectively.

Two-port VATS lobectomies, performed using either 3D or 2D in 165 patients a single thoracic centre, were no different in terms of clinical outcomes or operative time between the two groups (11).

All the above studies required the use of dedicated glasses to view 3D images. No adverse effects were reported by the operating surgeon, however, supporting staff did experience transient nausea, headaches and visual disturbances (7).

There is, additionally, emerging observational data for glasses-free 3D systems, with variable subjective rating and preference noted (12-14).

Discussion

Traditional 2D systems present a flat image of a 3D space, thus posing challenges in terms of depth perception. Compensating for this presents an additional cognitive load that compounds the challenges implicit in performing complex procedures using elongated instruments and with reduced tactile feedback.

3D HD systems may allow surgeons to operate with increased confidence, thus offering increased procedural efficiency, a lower complication rate and better safety profile for more intricate procedures previously not considered appropriate for a minimally-invasive approach.

Historical 3D technology was comparatively rudimentary, with poor resolution and often requiring users to wear battery-powered glasses or helmets—with implicit discomfort, particularly with prolonged use. Contemporary passive polarising systems are better tolerated, however, are still heavily dependent on accurate positioning of the user relative to the screen, with suboptimal viewing elevation, distance and laterality relative to the display unit resulting in cross-talk and a higher incidence of adverse effects (15). The use of autostereoscopic glasses-free 3D displays has only recently been described, but holds promise for improved viewing experience by multiple individuals at varying positions and distances from the screen (16). Early reports of trials in surgical settings have noted variable user experience and preference in comparison to contemporary passive-polarising systems (14,17).

Benchtop trials conducted using newer generation 3D HD systems have largely been consistent in demonstrating an improved accuracy, lower error rate, and shorter time to completing standardised tasks (18,19). The evidence for benefit is more robust in novice and intermediate surgeons, with less consistent results noted for improved outcomes in expert endoscopic surgeons (20-22). Subjective preference for 3D systems is almost universal, regardless of objective benefit derived; with the additional benefit of a reduced cognitive workload having been variably demonstrated (18,20,23).

More recently, clinical evidence from a variety of different surgical specialties has established the safety of adoption of this technology in the operating theatre, with the operative time frequently emerging as being reduced when using modern, as opposed to early-days, 3D HD technology, and for both minor (cholecystectomy) and major (bariatric procedures and liver resections) laparoscopic procedures (24-28).

This has not routinely translated to any measured benefit in clinical outcomes, with some exceptions. Li et al. report an improved thoracic lymph nodal dissection, as well as an enhanced recovery following 3D VATS oesophagectomy for malignancy: with earlier chest drain removal, shorter
hospital length of stay, quicker return to arm function, and a lower measured inflammatory response (29). They also demonstrated a cost-benefit to this approach.

There is no data available to indicate the degree of adoption of 3D MIS in routine clinical practice. Much resistance to its adoption arises from fears of facing the frequent adverse effects reported in the early trials in the 1990s, which is of limited relevance in view of interval technological advances.

The exact proportion of thoracic surgical procedures, and specifically lung resection, performed by VATS is difficult to quantify, however, resistance to wider adoption of a VATS approach to lobectomy is, in part, attributed to the perceived learning curve (30). This is estimated at 26 to 50 cases in various institutional reports, with no serious adverse events encountered in this initial period (31-33).

Despite the absence of clinical evidence, benchtop data indicates that the adoption of 3D technology may shorten the learning curve for the acquisition of novel techniques (34,35). Further evaluation of the validity of this approach in achieving competence in higher complexity tasks, as well as the potential for stepwise skill transferability to operating using conventional 2D HD systems is required. This approach should be considered in facilitating a wider uptake of the VATS approach for anatomic lung resection.

Currently, high-quality data for 3D HD thoracic surgery in major lung resection, remains limited.

One well-designed large randomised controlled study (8) reports outcomes from 300 patients randomised into two well-matched groups to undergo 3D or 2D VATS respectively, with a clearly-defined surgical approach at two high-volume institutions; but without standardised perioperative care, and with individual participating surgeons having an extremely high volume experience in performing VATS lobectomy (2,000 lobectomies prior to the trial). This vast individual experience renders the results poorly-generisable. Whilst the reported 18% (31 minutes) decrease in operative time is statistically significant, its impact on patient outcomes or theatre logistics is remains to be determined. The authors also fail to report objectively on surgeon and supporting staff experience and preference.

Future investigation into the role of 3D systems in VATS surgery should focus on patient centred outcomes, including pain over time. Postoperative pain, which may become chronic in nature, remains a complication in contemporary VATS. This is likely a result of leveraging of the thoracoscope to optimise operative views and better compensate for the absence of depth perception (36), causing intercostal nerve damage. The use of 3D systems may require less movement parallax, thus minimizing trauma and subsequent pain; although this has yet to be evaluated in practice.

Operator preference, confidence, ergonomics and fatigue should additionally be specifically evaluated in future trials; as these underpin the reach, rate and scope of expansion of MIS beyond current boundaries.

Conclusions

The current body of evidence speaks to the non-inferiority of 3D over conventional 2D visualisation systems in VATS for major lung resection. Further investigation is required to better define a niche for this technology in evolving clinical practice.

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Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

References


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