Review Article

Three-dimensional video-assisted thoracoscopic surgery in major lung resection

Edward J. Caruana

Thoracic Surgery, Glenfield Hospital, Leicester, UK

Correspondence to: Edward J. Caruana, MD, MRCSEd. Department of Thoracic Surgery, Glenfield Hospital, Groby Road, Leicester LE39QP, UK. Email: edwardcaruana@gmail.com.

Abstract: Thoracoscopic surgery has been potentiated by advances in technology since it was first embarked upon in the early 20th century. A review of the literature pertinent to the use of three-dimensional (3D) imaging in video-assisted thoracoscopic surgery was performed. There is little high-quality data available on this topic. Current evidence supports non-inferiority of 3D over conventional two-dimensional (2D) systems, with a shorter operative time as the sole consistently-noted benefit of this technology. Further investigation is warranted to better evaluate the role of 3D technology in improving patient-centred outcomes and further empowering clinicians to expand the scope of our practice.

Keywords: Three-dimensional (3D); thoracoscopy; video-assisted thoracic surgery (VATS); thoracic surgery

Received: 10 February 2017; Accepted: 23 February 2017; Published: 04 May 2017.

doi: 10.21037/vats.2017.03.04

View this article at: http://dx.doi.org/10.21037/vats.2017.03.04

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 underdo 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 levering 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.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Luca Bertolaccini and Piergiorgio Solli) for the series “VATS: the age of maturity” published in *Video-Assisted Thoracic Surgery*. The article has undergone external peer review.

Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/vats.2017.03.04). The series “VATS: the age of maturity” was commissioned by the editorial office without any funding or sponsorship. The author has no other conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Jacobaeus HC. The Cauterization of Adhesions in Artificial Pneumothorax Treatment of Pulmonary Tuberculosis under Thoracoscopic Control. Proc R Soc Med 1923;16:45-62.
2. Roviaro G, Rebuffat C, Varoli F, et al. Videoendoscopic pulmonary lobectomy for cancer. Surg Laparosc Endosc 1992;2:244-7.
3. Walker WS, Carnochan FM, Pugh GC. Thoracoscopic pulmonary lobectomy. Early operative experience and preliminary clinical results. J Thorac Cardiovasc Surg 1993;106:1111-7.
4. Marty-Ané CH, Canaud L, Solovei L, et al. Video-assisted thoracoscopic lobectomy: an unavoidable trend? A retrospective single-institution series of 410 cases. Interact Cardiovasc Thorac Surg 2013;17:36-43.
5. Flores RM, Ihekweazu U, Dycoco J, et al. Video-assisted thoracoscopic surgery (VATS) lobectomy: catastrophic intraoperative complications. J Thorac Cardiovasc Surg 2011;142:1412-7.
6. Dickhoff C, Li WW, Symersky P, et al. Feasibility of 3-dimensional video-assisted thoracic surgery (3D-VATS) for pulmonary resection. Ann Surg Innov Res 2015;9:8.
7. Bagan P, De Dominicis F, Hernigou J, et al. Complete thoracoscopic lobectomy for cancer: comparative study of three-dimensional high-definition with two-dimensional high-definition video systems. Interact Cardiovasc Thorac Surg 2015;20:820-3.
8. Yang C, Mo L, Ma Y, et al. A comparative analysis of lung cancer patients treated with lobectomy via three-dimensional video-assisted thoracoscopic surgery versus two-dimensional resection. J Thorac Dis 2015;7:1798-805.
9. Dong S, Yang XN, Zhong WZ, et al. Comparison of three-dimensional and two-dimensional visualization in video-assisted thoracoscopic lobectomy. Thorac Cancer 2016;7:530-4.
10. Yang CL, Wang W, Mo LL, et al. Short-Term Outcome of Three-Dimensional Versus Two-Dimensional Video-Assisted Thoracic Surgery for Benign Pulmonary Diseases. Ann Thorac Surg 2016;101:1297-302.
11. Jiao P, Wu QJ, Sun YG, et al. Comparative study of three-dimensional versus two-dimensional video-assisted thoracoscopic two-port lobectomy. Thorac Cancer 2017;8:3-7.
12. Li M. The world's first radical resection for lung cancer using glasses-free 3D thoracoscope was completed in Guangzhou. J Thorac Dis 2015;7:E384-5.
13. Shao W, Yin W, Wang W, et al. Glasses-free three-dimensional endoscopic bronchoplasty, arterioplasty, and angioplasty of the superior vena cava for the radical treatment of right middle upper lung cancer. J Thorac Dis 2016;8:608-11.
14. He J, Ang KL, Hao Z, et al. The comparison between novel and traditional three-dimensional image system in thoracoscopy: glasses-less vs. glass. J Thorac Dis 2016;8:3075-80.
15. Sakata S, Watson MO, Grove PM, et al. The Conflicting Evidence of Three-dimensional Displays in Laparoscopy: A Review of Systems Old and New. Ann Surg 2016;263:234-9.
16. Zhao D, Ma L, Ma C, et al. Floating autostereoscopic 3D display with multidimensional images for telesurgical visualization. Int J Comput Assist Radiol Surg 2016;11:207-15.
17. Khoshabeh R, Juang J, Talamini MA, et al. Multiview glasses-free 3-D laparoscopy. IEEE Trans Biomed Eng 2012;59:2859-65.
18. Usta TA, Ozkaynak A, Kovalak E, et al. An assessment of the new generation three-dimensional high definition laparoscopic vision system on surgical skills: a randomized prospective study. Surg Endosc 2015;29:2305-13.
19. Sørensen SM, Savran MM, Konge L, et al. Three-dimensional versus two-dimensional vision in laparoscopy: a systematic review. Surg Endosc 2016;30:11-23.
20. Smith R, Schwab K, Day A, et al. Effect of passive polarizing three-dimensional displays on surgical performance for experienced laparoscopic surgeons. Br J Surg 2014;101:1453-9.
21. Mashiach R, Mezhybovsky V, Nevler A, et al. Three-dimensional imaging improves surgical skill performance in a laparoscopic test model for both experienced and novice laparoscopic surgeons. Surg Endosc 2014;28:3489-93.
22. Cicione A, Autorino R, Breda A, et al. Three-dimensional vs standard laparoscopy: comparative assessment using a validated program for laparoscopic urologic skills. Urology 2013;82:1444-50.
23. Wilhelm D, Reiser S, Kohn N, et al. Comparative evaluation of HD 2D/3D laparoscopic monitors and benchmarking to a theoretically ideal 3D pseudodisplay: even well-experienced laparoscopists perform better with 3D. Surg Endosc 2014;28:2387-97.
24. Hanna GB, Shimi SM, Cuschieri A. Randomised study of influence of two-dimensional versus three-dimensional

imaging on performance of laparoscopic cholecystectomy. Lancet 1998;351:248-51.
25. Bilgen K, Ustün M, Karakahya M, et al. Comparison of 3D imaging and 2D imaging for performance time of laparoscopic cholecystectomy. Surg Laparosc Endosc Percutan Tech 2013;23:180-3.
26. Velayutham V, Fuks D, Nomi T, et al. 3D visualization reduces operating time when compared to high-definition 2D in laparoscopic liver resection: a case-matched study. Surg Endosc 2016;30:147-53.
27. Currò G, La Malfa G, Caizzone A, et al. Three-Dimensional (3D) Versus Two-Dimensional (2D) Laparoscopic Bariatric Surgery: a Single-Surgeon Prospective Randomized Comparative Study. Obes Surg 2015;25:2120-4.
28. Agrusa A, di Buono G, Chianetta D, et al. Three-dimensional (3D) versus two-dimensional (2D) laparoscopic adrenalectomy: A case-control study. Int J Surg 2016;28 Suppl 1:S114-7.
29. Li Z, Li JP, Qin X, et al. Three-dimensional vs two-dimensional video assisted thoracoscopic esophagectomy for patients with esophageal cancer. World J Gastroenterol 2015;21:10675-82.
30. Rocco G, Internullo E, Cassivi SD, et al. The variability of practice in minimally invasive thoracic surgery for pulmonary resections. Thorac Surg Clin 2008;18:235-47.
31. Yao F, Wang J, Yao J, et al. Video-Assisted Thoracic Surgical Lobectomy for Lung Cancer: Description of a Learning Curve. J Laparoendosc Adv Surg Tech A 2017. [Epub ahead of print].
32. Gonfiotti A, Bongiolatti S, Borgianni S, et al. Development of a video-assisted thoracoscopic lobectomy program in a single institution: results before and after completion of the learning curve. J Cardiothorac Surg 2016;11:130.
33. Zhao H, Bu L, Yang F, et al. Video-assisted thoracoscopic surgery lobectomy for lung cancer: the learning curve. World J Surg 2010;34:2368-72.
34. Ashraf A, Collins D, Whelan M, et al. Three-dimensional (3D) simulation versus two-dimensional (2D) enhances surgical skills acquisition in standardised laparoscopic tasks: a before and after study. Int J Surg 2015;14:12-6.
35. Poudel S, Kurashima Y, Watanabe Y, et al. Impact of 3D in the training of basic laparoscopic skills and its transferability to 2D environment: a prospective randomized controlled trial. Surg Endosc 2017;31:1111-8.
36. Voorhorst FA, Overbeeke KJ, Smets GJ. Using movement parallax for 3D laparoscopy. Med Prog Technol 1996-1997;21:211-8.

doi: 10.21037/vats.2017.03.04
Cite this article as: Caruana EJ. Three-dimensional video-assisted thoracoscopic surgery in major lung resection. Video-assist Thorac Surg 2017;2:28.

