Case Report: Application of HoloLens for Intra-Operative Assessment of a Retrosternal Thyroid Goitre

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Abstract

Thyroidectomy is a common surgical procedure performed to treat a myriad of thyroid pathologies. 2-19% of thyroidectomies involve a retrosternal goitre, which is an extension of thyroid tissue into the thoracic cavity. Resection of retrosternal goitres are more challenging that standard thyroidectomies and typically have higher complication rate of recurrent laryngeal nerve injury, hypoparathyroidism and post op bleeding. Goitres can be removed either via a transcervical approach, transthoracic approach or a combination of both. A transcervical approach is generally favoured. Direct visualisation of the lower poles of the goitre is challenging in such scenarios, making it difficult to confirm full removal of the goitre. Retrosternal goitres are usually evaluated and characterised with cross-sectional imaging such as a computed tomography (CT) scan, in order to estimate the size and location of the goitre. We demonstrate a mixed reality technique of visualising retrosternal goitres, involving projecting three-dimensional (3D) reconstruction of the CT scan onto the patient to directly visualise the size and location of the goitre. This guides surgeons in the removal of retrosternal goitres, with the aim to reduce complications and facilitate complete excision of the goitre. We believe that HoloLens2 is a novel new adjunct which will aid surgeons in future surgeries involving a retrosternal goitre.

Introduction

Retrosternal goitre was originally described as an inferior extension of an enlarged thyroid gland into the thoracic inlet [1] but is currently most often defined as a thyroid gland with > 50% of its mass within the mediastinum [2–4]. Surgery for symptomatic disease or malignancy is the treatment of choice in suitable patients, with the options of transcervical, midline sternotomy or lateral thoracotomy approaches. The rate of complications associated with the transcervical approach is lower compared to the other approaches [5, 6] which are only required in 1–11% of patients with a retrosternal goitre [7]. However, the risk of complications is higher with retrosternal goitres than with cervical goitres [8]. Such risks include the higher rate of permanent hypoparathyroidism and permanent recurrent laryngeal nerve injury [9] and post-op bleeding [8]. Due to inability to easily visualise or palpate the inferior-most border of the thyroid gland, there is also the risk of incomplete excision of the retrosternal goitre, resulting in residual thyroid tissue left in the mediastinum.

To the authors’ knowledge, this is the first reported case of a large retrosternal goitre excision that has been assisted by HoloLens2 Mixed Reality (MR) technology (Microsoft Corporation, Redmond, WA, USA) and Virtual Surgery Intelligence (VSI – apoQlar GmbH, Hamburg, Germany). The MR technology assists the surgeon in projecting a holographic reconstruction of the patient’s pre-operative computed tomography (CT) image over the patient’s body during surgical dissection to assist in visualisation of the goitre’s full extent. Our report aims to suggest the feasibility of this novel technique to facilitate safe and complete dissection of the retrosternal goitre.

Case Report
Our patient was a 57-year-old female who underwent elective total thyroidectomy for a retrosternal goitre complicated by extrinsic airway compression. She initially presented with a gradually enlarging neck mass and dyspnoea. The patient did not have dysphagia or clinical evidence of vascular compression, and history was negative for previous head and neck irradiation or familial history of thyroid disease or malignancy. Physical examination revealed a large multinodular goitre with retrosternal extension, and no clinically palpable lymph nodes. The patient was clinically and biochemically euthyroid.

A pre-operative CT scan of the neck and thorax (Fig. 1) revealed a large multinodular goiter with antero-posterior compression and rightward displacement of the trachea. The narrowest diameter of the trachea was six millimetres at the level of the clavicles. There was retrosternal extension until the aortic arch. There was no radiological evidence of extra-thyroidal extension or cervical lymphadenopathy. The patient underwent surgery after one year of conservative management, because she developed increasing breathlessness from the goitre.

Pre-operative CT images of the neck and thorax with three-millimeter fine cuts were obtained and reconstructed for the HoloLens. The surgery was performed under general anaesthesia, and the patient was positioned supine with a shoulder roll and the neck in extension. A transcervical approach was undertaken via a collar line skin incision. Platysmal flaps were raised and the strap muscles were divided. Intraoperatively, the multinodular goitre's right lobe measured ten by eight centimeters, while the left lobe measured eleven by five centimeters. The left lower pole extended retrosternally and trachea rings were firm with no evidence of tracheomalacia. Routine capsular dissection was performed for bilateral thyroid lobes with preservation of the parathyroid glands and intra-operative nerve monitoring of the recurrent laryngeal nerves.

Next, the left strap muscles were divided and the retrosternal extension of the goitre was evaluated with aid of the HoloLens MR technology (Fig. 2). Clinical assessment with palpation was done by the lead operating surgeon, with confirmation of the inferior-most extent of the thyroid gland with visualisation on MR. Dissection of the retrosternal goitre was performed within the upper mediastinum, and the extent of surgical dissection was re-evaluated using MR to ensure adequate resection had been completed. Haemostasis was secured and the wound was closed in layers. Operative time was 180 minutes, and estimated blood loss was less than 50 milliliters. The dissected goitre is pictured in Fig. 3.

Post-operatively, the patient had an uneventful recovery. There were no complications, including hypocalcemia, hypoparathyroidism, tracheomalacia or neck haematoma. Final histopathology confirmed a multi-nodular goitre with no malignancy or dysplasia.

**Discussion**

The HoloLens2 is a head-worn, optically see-through MR display which combines virtual and augmented reality to provide surgeons with an immersive, 3D view of the surgical field [10]. It allows for scan images to be reconstructed and projected as a hologram nearby or superimposed over the patient's body. This technology seeks to provide surgeons with detailed and continuous visualisation of the individual
patient’s anatomy during surgical procedures. MR technology has been applied in various surgical procedures to improve anatomy visualisation and dissection accuracy, including neurosurgery [11], venipuncture [12], hepatobiliary and transplant surgery [13], and craniomaxillofacial plastic surgery [14].

In our case report, the extent of retrosternal extension was well visualised using the HoloLens and assisted the lead operating surgeon in intra-operative confirmation of the inferior-most extent of the retrosternal goitre. The MR projection allowed visualisation of key relations of the retrosternal goitre including the innominate vessel, and this was essential in facilitating safe dissection of the goitre within the upper mediastinum.

At present, there is a paucity of research on the use of HoloLens in thyroid surgery, including for retrosternal goitres. The authors postulate that utilisation of this novel technique may reduce the rate of incomplete dissection and surgical complications for large multinodular goitres with retrosternal extension. MR technology may prove to be exceptionally useful in cases with intricate anatomy such as retrosternal goitrous extension, as surgery is more complex and challenging than standard thyroidectomy due to difficulty in accessing the surgical site. Other potentially uses in thyroid surgery could include oncological resection of locally-advanced cancer and neck exploration with lymphadenectomy.

Image registration is one of the crucial components required to ensure accurate overlay and superimposition of a patient’s scan onto their body during the surgery. At present, this is performed manually based on identifiable landmarks on the patient’s body and the scan. This is however, inconsistent and would require the user to spend substantial time to ensure accurate alignment and image registration. A method for auto registration is needed to facilitate quick and accurate registration of patient scans, and the ability to adjust for patient and tissue movement during the surgery.

For this patient, we used the raw DICOM images from the patient’s CT scan for 3D rendering and image reference. Segmented images may be used for future cases to highlight important and relevant structures, while digitally subtracting areas that are less pertinent. This will help to reduce image clutter and simplify the user interface and image display.

Further study into the utilisation of HoloLens MR technology in endocrine surgery could include intra-operative localisation of parathyroid glands including ectopic intra-thoracic glands, with the reconstruction of single photon emission computed tomography (SPECT) scans or 4D CT scans.

Conclusion

The use of HoloLens in large retrosternal goitres is a novel technique to aid surgeons in applying information from CT scans intra-operatively. We propose that the use of Hololens to identify the inferior border of the thyroid and the surrounding structures helps to reduce the complications and thus the morbidity and mortality of such surgeries.

Declarations
Ethics approval and consent to participate

This case report did not require ethics board approval. All participants have given informed consent for participation.

Consent for publication

All authors and participants have given informed consent for publication. Patient provided informed consent for publication of the study.

Availability of data and materials

Competing interests

None

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None

Authors’ contributions

EKFL was responsible for literature review, writing and paper revision.

AC was responsible for literature review, writing and paper revision.

LWKJ was responsible for literature review, paper revision, critique and quality assessment.

GYJ was responsible for paper revision, critique and quality assessment.

NKY was responsible for formulation of the article, paper revision, critique and quality assessment.

References


**Figures**

**Figure 1**

Pre-operative CT scan of the neck and thorax demonstrating retrosternal extension of the goitre to the level of the aortic arch and extrinsic tracheal compression
Figure 2
Intra-operative assessment of the retrosternal goitre with aid of the HoloLens MR projection
Figure 3

Clinical photograph of thyroidectomy specimen