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TECHNICAL NOTE

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# Remotely shared CT-derived presurgical understanding of lung cancer: A randomized trial

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**Abstract**

Shared decision-making is imperative for patient-and family-centered care. However, gathering individuals in a single place was challenged by modern life and pandemic restrictions. This study conducted a 1:1 randomized trial to examine the feasibility of a CT-derived 3D virtual explanation module for lung cancer to improve the understanding of patients and third parties in physically separate locations. We prospectively enrolled adults in whom elective surgical resection for lung cancer was planned at a single tertiary hospital in 2020. From presurgical CT scans, deep neural networks automatically segmented lung cancer, airway, pulmonary lobes, skin, and bony thorax. The segmented structures were subsequently transformed into an anonymized interactive 3D module which comprised a standardized scenario with explanatory texts. The intervention group received a link to the module on their smartphone before admission and could repeatedly access the link or transfer it to patients' third parties. A total of 33 and 29 patients were enrolled in the intervention and control arms. The understanding score did not statistically differ between the arms (mean difference, 0.7 [95% CI: −0.2, 1.5]; $p = 0.13$). However, 76% of patients in the intervention arm accessed the link, and patient median access count was 14. The link recipients of third parties had comparable understanding scores to the patients (mean difference, −0.2 [95% CI: −1.9, 1.5]; $p = 1.00$), indicating that the understanding could be shared remotely with patients and patients' third parties. In conclusion, it was feasible that people physically separated from patients obtained a comparable understanding of lung cancer surgery using the patient's CT-derived 3D virtual explanation module.

**KEYWORDS**
lung cancer, computed tomography, 3D understanding

## INTRODUCTION

Shared decision-making is imperative for patient-centered care.[1] Patients frequently accompany people close to them represented by family in informed consent[2] and cancer treatment decision.[3,4] Doctor-patient-companion communication can differ broadly[5] but is frequently perceived as helpful.[6] Cancer patients require multifaceted support, and the appropriate family understanding of patient disease is a basis of family support and relationships with

† Both authors contributed equally to this work.

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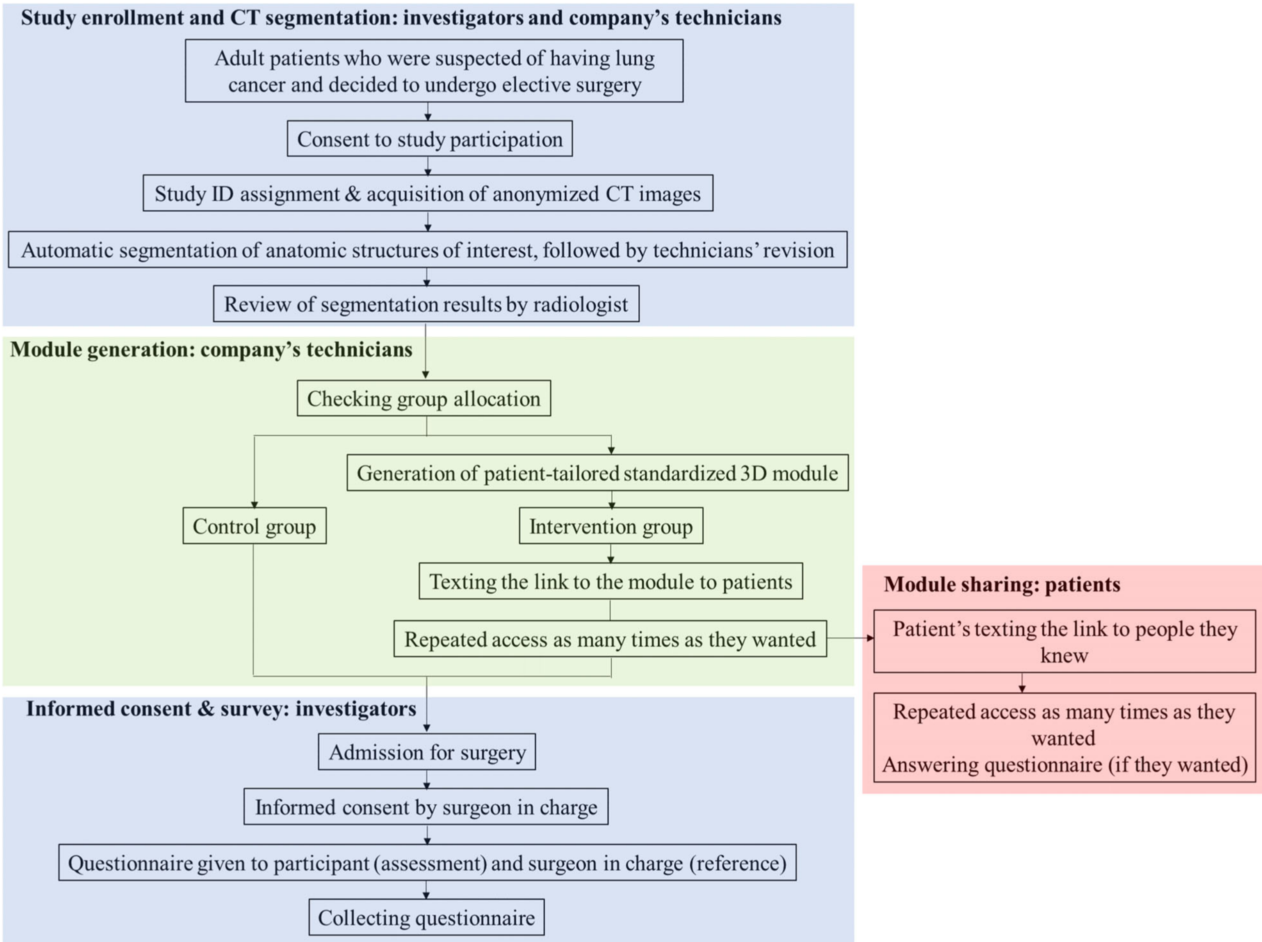


**FIGURE 1** Study flow diagram

patients.[7–9] Indeed, family support can affect physicians' treatment decisions[10] and patient survival.[11]

The roles of radiologists are emphasized in patient-centered care and are essential for radiology's long-term sustainability.[12] Effective communication about patient diseases is one of the key factors for patient-centered radiology and family involvement in patient care.[13] Indeed, radiology practices are involved in all steps of cancer diagnosis, staging, and treatment decisions. Nevertheless, in a previous study, it was found that radiologists' communication was not sufficiently provided due to time or workload.[14] Moreover, the recent shift toward telehealth during the pandemic has been reported to lead to less frequent personal contact between radiologists and patients.[15] Aspects of modern life and pandemic restrictions have also made it challenging to gather individuals in a single place, threatening the involvement of patients' companions.[16]

This study examined the feasibility of a CT-derived personalized 3D virtual explanation module for lung cancer and evaluated whether the module improved the understanding of lung surgery in patients and third parties in physically separate locations.

## METHODS

The institutional review board approved this prospective, single-blinded, randomized controlled study (registration, KCT0004481 at https://cris.nih.go.kr), and all participants provided informed consent.

We enrolled adult patients who were suspected of having lung cancer on a preoperative multidetector chest CT examination, had a smartphone and decided to undergo elective surgical resection at a single tertiary hospital in 2020. We excluded patients who had difficulty communicating and reading. The preplanned study population number was 66 based on a prior study,[17] assuming that those groups would have average scores of 7 and 5.5 for nine items, respectively (standard deviation: 2; alpha error: 0.05; beta error: 0.2; drop-out rate: 10%). Participants were randomly allocated in a 1:1 ratio using a web-based randomization system. Only company technicians received the randomization list; the investigators were blinded to group allocation.

Upon enrollment, the areas of lung cancer, airway, pulmonary lobes, skin, and bony thorax were segmented from pre-existing presurgical CT scans using deep neural networks of commercially available software (Medip Pro 2.0; Medical IP)[18,19]

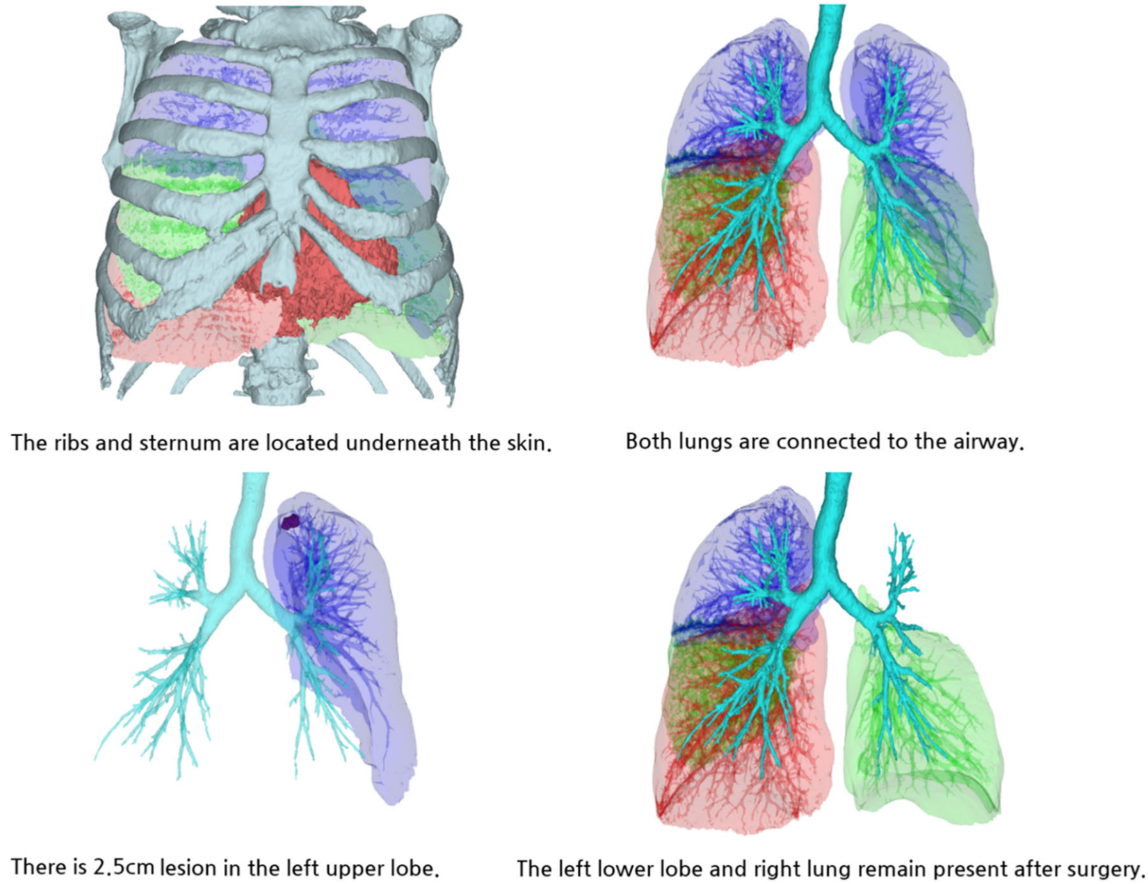


**FIGURE 2** Representative screenshots in the patient-specific 3D virtual explanation module

**TABLE 1** Questionnaire to assess understanding between patients and third parties

| **Basic anatomy** | |
|---|---|
| 1. The lungs are located in the middle of the chest | True; False; Not sure |
| 2. The lung is a paired organ. | True; False; Not sure |
| 3. One lung can be divided into two or three lobes. | True; False; Not sure |
| 4. There are bronchi and blood vessels inside the lungs. | True; False; Not sure |
| **Lung cancer** | |
| 5. Where is lung cancer located? (please choose the largest one, if multiple) | Right upper lobe; Right middle lobe; Right lower lobe; Left upper lobe; Left lower lobe; Not sure |
| 6. What is the size of the lung cancer? | <3 cm; 3-5 cm; 5-7 cm; ≥7 cm; Not sure |
| 7. How many lesions are suspected to be lung cancer? | 1; 2; ≥3; Not sure |
| **Surgery** | |
| 8. Only lung cancer is resected, not its surrounding areas. | True; False; Not sure |
| 9. Surgeons will resect the entire pulmonary lobe that includes lung cancer. | True; False; Not sure |

and revised by technicians if necessary (Figure 1). The software subsequently transformed the structures to generate an anonymized interactive 3D virtual explanation module (example, http://147.47.229.147:9090/mediclip/d613a51c8ef54ac593d19f091ac280bb-patient.php; Movie S1). The module comprised a standardized scenario beginning from a patient-specific view of the thorax to lung cancer with explanatory texts (Figure 2). Patients in the intervention group received a link to the module through a text message to their smartphone before admission for surgery. The median interval between patient enrollment and texting the link of the virtual 3D model was 1 day (interquartile range, 1–3 days).

Patients could repeatedly access the module and text the link module to people they knew. After admission, one surgeon dedicated to the informed consent process explained the content verbally using a standardized institutional document. The control group received a verbal explanation without the module. Both groups then answered a questionnaire consisting of nine items testing patient understanding of basic anatomy, lung cancer, and surgery (Table 1). The primary outcome was the difference in patients who understood the score between the intervention and control groups. Secondary outcomes were as follows: the difference in adherence rate between intervention and control groups; patient access count to the link; the difference in the

**TABLE 2** Baseline characteristics

| | | Intervention group ($n = 33$) | Control group ($n = 29$) | $p$-value |
|---|---|---|---|---|
| Age (years) | | 62.0 ± 10.2 | 61.4 ± 10.1 | 0.93 |
| Male | | 11 (33%) | 14 (48%) | 0.30 |
| Multiplicity | Single lesion | 24 (73%) | 23 (79%) | 0.57 |
| | Multiple lesions | 9 (27%) | 6 (21%) | |
| Largest lesion location | Right upper lobe | 8 (24%) | 12 (41%) | 0.01 |
| | Right middle lobe | 3 (9%) | 1 (3%) | |
| | Right lower lobe | 5 (15%) | 12 (41%) | |
| | Left upper lobe | 9 (27%) | 3 (10%) | |
| | Left lower lobe | 8 (24%) | 1 (3%) | |
| Surgery | Lobectomy | 22 (67%) | 21 (69%) | 0.15 |
| | Segmentectomy | 7 (21%) | 8 (31%) | |
| | Wedge resection | 4 (12%) | 0 (0%) | |
| Pathology | Adenocarcinoma | 25 (60%) | 27 (75%) | 0.68 |
| | MIA/AIS | 4 (10%) | 3 (8%) | |
| | Squamous | 4 (10%) | 2 (6%) | |
| | Other NSCLC or SCLC | 2 (5%) | 1 (3%) | |
| | Benign lesions | 7 (17%) | 3 (8%) | |
| Pathological size of the largest lesion (cm) | Total tumor size | 2.5 ± 1.9 | 2.3 ± 1.1 | 0.64 |
| | Invasive component | 2.3 ± 2.0 | 2.0 ± 1.3 | 0.92 |
| Pathological T descriptor[a] | Tmi | 3 (9%) | 2 (7%) | 0.89 |
| | T1a | 4 (12%) | 4 (14%) | |
| | T1b | 10 (30%) | 10 (34%) | |
| | T1c | 3 (9%) | 5 (17%) | |
| | T2 | 10 (24%) | 6 (21%) | |
| | T3-4 | 3 (9%) | 2 (7%) | |
| Pathological N descriptor[a] | N0 | 27 (82%) | 25 (86%) | 0.40 |
| | N1-2 | 4 (12%) | 4 (14%) | |
| | Nx | 2 (6%) | 0 (0%) | |

Abbreviations: AIS, adenocarcinoma in situ; MIA, minimally invasive adenocarcinoma; NSCLC, non-small cell lung cancer; SCLC, small cell lung cancer.
[a]T, N descriptors were assessed based on the eighth edition of the TNM Classification for Lung Cancer.

understanding score between the intervention group who accessed the link and the control/intervention group without the access (per-protocol analysis); and the difference in the understanding score between third parties and patients who sent the link to them. The surgeons' answers served as a reference. Mann–Whitney, Fisher's and signed-rank tests were used to compare groups.

## RESULTS

Among 34 and 32 enrolled patients in the intervention and control arms, one and three patients, respectively, chose not to undergo surgery (adherence rate, 97%; [95% CI: 84–99%] vs. 91%; [95% CI: 75–97%]; $p = 0.35$), resulting in 33 and 29 patients for analysis (Table 2). The difference in the understanding score was statistically nonsignificant (7.2 ± 1.6 vs. 6.5 ± 1.8; mean difference, 0.7 [95% CI: −0.2, 1.5]; $p = 0.13$). Patients who accessed the link had nonsignificantly higher understanding scores than those who did not access the link (7.4 ± 1.2 vs. 6.5 ± 1.8; mean difference, 0.8 [95% CI: −0.1, 1.6]; $p = 0.10$). Furthermore, 25 patients (76% [95% CI: 59–87%]) in the intervention arm accessed the link, and patients' median access count was 14 (interquartile range, 7–18). Eleven patients (44% [95% CI: 27–63%]) texted it to third parties (up to 10 people), of whom nine replied to the questionnaire. The link recipients' scores were comparable to the patients' scores (6.9 ± 2.0 vs. 7.1 ± 2.6; mean difference, −0.2 [95% CI: −1.9, 1.5]; $p = 1.00$).

## DISCUSSION

The CT-derived 3D module comprised the standardized instructional visual explanation of patient-specific 3D images but failed to significantly improve patient presurgical understanding. The failure could be primarily related to the module access: one-fourth of patients did not access the module, and had a lower understanding score than patients who accessed the link. Unfortunately, we could not identify why patients did not access the link. It may have been the result of a technical problem hindering access from the vast number of commercial smart phones available, or the link recipients might have forgotten the study enrollment and regard the link as spam. The access to the link will be improved by checking the accessibility to the example module using patients' smartphones and introducing how to access the link for the patients in person at the time of enrollment.

Three-fourths of the patients actively accessed the module several times and texted the link to people they knew, thereby successfully sharing patients' understanding. Health literacy is a critical factor in cancer communication,[20] and the public, especially those with limited health literacy, or who have an insufficient basic anatomic understanding of the human body.[20,21] The radiology report may be transferred remotely to third parties, but readability is affected considerably by education level.[22] Image is a more effective measure than text in health communication,[23] and the effect increases with instructional animation.[24] Pre-existing written/audiovisual materials or decision aids helped improve patient knowledge,[25] but those were neither personalized using patient data nor tested for patient third parties physically apart.

The module was automatically generated based on automatic CT segmentation of deep neural networks. The radiologist typically spent a few minutes reviewing the segmentation result and inputting essential information regarding lung cancer location, number, and size. The module generation followed by texting the link usually took 1 day after enrollment, and it got shortened further compared to 2 weeks in our preliminary trial using 3D printing.[17] The module did not substantially increase the workload of radiologists and the time and workload spent generating the module may be comparable or smaller to in-person communication for explaining patient diseases. Transforming cross-sectional images into 3D explanation modules can be an option for delivering image information of patient diseases remotely for patient and family-centered radiology,[26] although reimbursement hurdles remain in promoting radiologist and patient communication.[14] Furthermore, it will be beneficial for the patient to consult another physician about illness remotely or to share tumor localization distantly in multidisciplinary management.[27] It may also be used as proof that surgeons sufficiently explain patient disease and surgery in a standardized form.

This study had several limitations. First, it was a single-institutional study with a relatively small number of patients. Second, patients might have explained their diseases to the link recipients priorly. Third, education levels and relationships of patients or recipients were not available due to privacy restrictions. In addition, we could not evaluate users' experiences of the module. Fourth, patients and third parties might have had difficulty using and understanding the 3D module by themselves. Doctors' voice recording or text-to-speech tools may boost content delivery in the explanation module. Fifth, the logic of explanation and visualization of lung cancer might be too complex for the patients and third parties in the module. Sixth, the researchers generated the questionnaire, and it was not thoroughly reviewed by relevant experts. The questionnaire may not be optimized to measure the improved understanding sufficiently. Seventh, only two enrolled patients were preoperatively suspected of having lymph node metastasis in the interlobar station. We did not visualize the suspected lymph node in the module as a lymph node segmentation required additional manual procedure hampering the automated process. Further studies in the future warrant visualization of metastatic lymph nodes in the virtual module in the automated process.

In conclusion, it was feasible that people physically separated from patients obtained a comparable understanding of lung cancer surgery using a personalized 3D virtual explanation module derived from the presurgical CT scans of patients. The CT-derived personalized explanation tool may provide a new opportunity for patient-centered radiology and promote the awareness of radiology's role in cancer patients.

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## CONFLICT OF INTEREST

The authors have norelevant conflicts of interest to disclose.

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## SUPPORTING INFORMATION

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