Evaluation of a Smart After-Care Program for Patients with Lung Cancer: A Prospective, Single-Arm Pilot Study

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Background: The efficacy of telemedicine among cancer survivors is uncertain. The Smart After-Care Program (SAP), which is an interactive, smartphone-based remote health monitoring system, was developed to help patients manage their health after leaving the hospital. This study was designed to evaluate the efficacy of our remote health care program for lung cancer patients.

Methods: We enrolled 50 patients with lung cancer. Self-monitoring devices were supplied to all patients, who were instructed to enter their daily vital signs and subjective symptoms to the Smart After-Care app. The app also provided information about rehabilitation exercises and a healthy diet for lung cancer patients. All patients received health counseling via telephone once a week and visited an outpatient clinic during weeks 6 and 12 to assess satisfaction with the SAP and changes in quality of life and physical performance.

Results: Overall satisfaction with the SAP was very high (very good, 61.9%; good, 26.2%). In the multivariate analysis to identify factors affecting satisfaction, the distance between the patient’s residence and the hospital was the only significant independent factor (p=0.013). Quality of life improved along all functional scales (p<0.05). Muscle strength significantly improved in the lower limbs (p=0.012). Two-minute walk distance also significantly improved (p=0.028).

Conclusion: This study demonstrated that the SAP was acceptable for and supportive of patients with reduced pulmonary function after lung cancer treatment. The SAP was found to be particularly useful for patients living far from the hospital.

Keywords: Smartphone, Telemedicine, Delivery of health care, Rehabilitation, Neoplasms

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In addition, lung cancer necessarily causes the deterioration of respiratory function [11,12]. Thus, lung cancer survivors may be more worried about their health than patients with other cancers. Providing these patients with health self-monitoring tools may help motivate them to adhere to respiratory rehabilitation programs by allowing them to recognize quantified improvements in function. Additionally, these tools may assist in the early detection of physical deterioration.

The primary purpose of this study was to investigate satisfaction with the SAP among lung cancer patients and to identify factors affecting satisfaction. The secondary purpose was to determine whether this program helped improve quality of life (QOL), cardiorespiratory endurance, and muscle strength.

Methods

This study was conducted among patients with lung cancer who were receiving outpatient chemotherapy or making regular outpatient visits after lung resection surgery. The study was approved by the National Cancer Center Institutional Review Board (NCC2015-0205). Written informed consent was obtained from each participant before registration.

Enrollment commenced in August 2015, and a total of 50 patients were recruited from a single institution over 3 months (Fig. 1). Subjects who owned an Android smartphone (version 4.3 or later) were eligible to participate if they: (1) were over 18 and under 85 years old, (2) consented to participate in the study, (3) had relatively stable comorbid conditions (if any), and (4) were willing to follow the study protocol. Subjects were excluded if: (1) giving feedback via a smartphone was deemed to be difficult for them, (2) they had a history of any serious illness other than lung cancer, or (3) they had difficulties performing rehabilitation exercises.

Among a total of 50 patients, 46 were undergoing outpatient observation after lung resection surgery for lung cancer, while the remaining 4 patients were undergoing chemotherapy±radiation treatment for advanced lung cancer without surgery. The average patient age was 58.3±11.7 years, with 28 men and 22 women, and the average body mass index (BMI) was 23.4±2.8 kg/m². Twenty-seven pa-

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**Fig. 1.** Flow diagram and overview of timeline. FEV1, forced expiratory volume within 1 second; EORTC, European Organization for Research and Treatment of Cancer; EORTC QLQ-C30, EORTC Core Quality of Life Questionnaire; EORTC QLQ-L13, EORTC Quality of Life Questionnaire-Lung Cancer 13; IPAQ-SF, International Physical Activity Questionnaire-Short Form.
patients had stage I, 6 had stage II, 12 stage III, and 5 stage IV lung cancer. Of the 46 patients who underwent surgery, 35 underwent lobectomy, 8 underwent wedge resection, 2 underwent segmentectomy, and 1 underwent pneumonectomy (Table 1). During the study, 8 (16%) of the 50 patients dropped out. Among them were 5 patients (10%) who complained of the burden associated with taking measurements using the devices and inputting them into the app, 2 patients (4%) who were forced to drop out due to cancer progression, and 1 patient (2%) who did not feel a need for the program. Data analysis was conducted for the remaining 42 patients, who recorded their vital signs and completed a symptom checklist each day, participated in a weekly telephone health consultation, and completed an assessment of physical ability in the department of rehabilitation.

Of the remaining 38 patients who had undergone lung surgery, 12 patients were enrolled in the study less than 2 months after surgery, 6 patients were enrolled more than 2 months but less than 1 year after surgery, and 20 patients were enrolled more than 1 year after surgery.

All subjects visited the hospital 3 times over 3 months, at 6-week intervals. At initial registration, patients completed a baseline QOL survey (EORTC-QLQ C30 and LC13). The EORTC-QLQ C30 is the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire, which consists of a set of 30 validated core questions assessing QOL in cancer patients, and the EORTC-QLQ LC13 is a modular supplement containing 13 questions specific to patients with lung cancer [13]. Patients also completed a 2-minute walk test to measure cardiorespiratory endurance, a 30-second chair stand test to measure lower extremity muscle strength, a handgrip strength test to measure upper extremity muscle strength, and the International Physical Activity Questionnaire-Short Form [14]. Based on these results, patients received exercise instructions and training from rehabilitation specialists and returned to the rehabilitation department at weeks 6 and 12 of the study to receive additional exercise training and to re-assess exercise performance. The SAP satisfaction survey was conducted when patients visited the hospital during weeks 6 and 12, and QOL questionnaires given at the beginning and end of the study were compared.

### Table 1. Patient characteristics: Smart After-Care participant data (n=50)

| Characteristic                           | Value          |
|-----------------------------------------|----------------|
| **Basic personal information**          |                |
| Age (yr)                                | 58.0±11.9      |
| Sex                                     |                |
| Male                                    | 28 (56)        |
| Female                                  | 22 (44)        |
| Body mass index (kg/m²)                 | 23.4±2.8       |
| Comorbidities                           |                |
| Hypertension                            | 9 (18)         |
| Diabetes                                | 5 (10)         |
| **Smoking status**                      |                |
| Current                                 | 17 (34)        |
| Never                                   | 26 (52)        |
| Ex-smoker                               | 7 (14)         |
| **Lung cancer stage (AJCC eighth edition)** |            |
| IA                                      | 19 (38)        |
| IB                                      | 8 (16)         |
| IIA                                     | 3 (6)          |
| IIB                                     | 3 (6)          |
| IIIA                                    | 12 (24)        |
| IIIB                                    | 0              |
| IV                                      | 5 (10)         |
| **Treatment**                           |                |
| Lobectomy                               | 35 (70)        |
| Wedge resection                         | 8 (16)         |
| Pneumonectomy                           | 1 (2)          |
| Segmentectomy                           | 2 (4)          |
| Chemotherapy±RT (no surgery)            | 4 (8)          |

Table values are presented as mean±standard deviation or number (%). AJCC, American Joint Committee on Cancer; RT, radiotherapy.

### Smart After-Care Program

**Self-monitoring devices**

We provided self-monitoring devices to all subjects and installed the Smart After-Care app on their smartphones. The self-monitoring devices included a Bluetooth electronic sphygmomanometer (UA-851PBT-C; A&D Electronics Co. Ltd., Shen Zhen, China), a finger pulse oximeter (Onyx Vantage 9590; Nonin Medical, Plymouth, MN, USA), and a digital spirometer (PF-200; Microlife Corp., Widnau, Switzerland). The devices were chosen based on the characteristics of lung cancer patients and enabled blood pressure, heart rate, oxygen saturation, and forced expiratory volume within 1 second (FEV1) to be obtained every morning. All participants were instructed to enter their daily vital signs into their smartphones. In addition, all participants were instructed to respond to a 13-question, lung cancer-specific checklist regarding their subjective physical state in the app (Fig. 2). If participants failed to properly input the information, the app was set to sound an alarm at 8 AM and 10 AM, and if a patient (1) failed to input the information for 3 consecutive days, (2) had an oxygen saturation of less than 95%, (3) had a heart rate above 120 beats/min or below 50 beats/min, (4) had systolic blood pressure...
above 180 mm Hg or below 80 mm Hg, (5) had diastolic blood pressure above 110 mm Hg, or (6) had an FEV1 that was more than 30% lower than that patient’s baseline level, the counseling center was notified and called the patient (Fig. 3).

**Smart After-Care application**

The Smart After-Care application was built specifically for this study, ran on the Android operating system, and included a personalized exercise and diet program for lung cancer patients in addition to recording vital signs. To encourage compliance with the prescribed exercise program, each movement was designed to be easy to follow, with a video clip for demonstration. The exercises consisted of muscle strength exercises using elastic bands, stretching exercises to increase flexibility, and breathing exercises to strengthen respiratory muscles.

Good nutrition plays an important role in improving health as well as in the treatment of disease [15]. Particularly among cancer survivors, nutritional problems such as lack of appetite are frequent. To address these problems, in this study, the BMI values of patients were calculated and classified into 6 grades according to the BMI classification criteria of the Korean Society of Obesity. Based on BMI grade, individual nutritional requirements were calculated using the Mifflin-St. Jeror formula [16]. These individual nutritional requirements were divided into 8 groups, and 12 personalized diets were provided for each group through...
the app. Patients were able to check menu-specific nutrients, dietary calories, and special recipe videos at any time (Fig. 4).

Survey information

Survey of SAP satisfaction

The satisfaction survey consisted of 4 main categories, as follows: (1) overall satisfaction with the SAP and willingness to use it after this study (4 questions), (2) satisfaction with the equipment and programs used in the SAP (6 questions), (3) service usability (7 questions), and (4) satisfaction with the telephone health counseling conducted by the counseling center (5 questions). Each question had 5 response choices, as follows: (1) very good (absolutely yes), (2) good (yes), (3) fair (average), (4) poor (no), and (5) very poor (absolutely no).

The answers were standardized for statistical analysis. We investigated the independent associations between satisfaction level and relevant clinical factors via the Kruskal-Wallis test.

Survey of QOL

The EORTC QLQ-30 assessment consists of a functional scale and a symptom scale. The functional scale is divided into 6 categories: global health status, physical functioning, role functioning, emotional functioning, cognitive functioning, and social functioning. The symptom scale consists of 8 symptoms: nausea/vomiting, pain, dyspnea, insomnia, appetite, constipation, and diarrhea. In addition, this study incorporated the EORTC QLQ-LC13, developed as a QOL survey for lung cancer patients. The survey consists of 13 questions about cough, hemoptysis, dyspnea, sore mouth, dysphagia, peripheral neuropathy, alopecia, pain in the chest, pain in the arm/shoulder, and other pain. Scores were calculated according to the EORTC QLQ-C30 version 3.0 scoring manual [17]. The QOL score changes for each area were compared using the Wilcoxon signed-rank test (1-sided, H1: before<after).

Statistical analysis

STATA ver. 13.0 software (Stata Corp., College Station, TX, USA) was used for statistical analysis and data processing. Continuous variables are represented by means±standard deviations, and categorical variables are presented as median values. For continuous variables, within-group post-hoc comparisons were performed using the Wilcoxon
rank-sum test (1-sided). A p-value of less than 0.05 was considered to indicate statistical significance.

**Results**

For internal validation of the SAP satisfaction survey, item internal consistency was calculated to determine whether each of the 4 categories was consistently organized, and item discriminant validity [18,19] was calculated to determine whether each of the categories was adequately separated from the others. The Cronbach \( \alpha \) value was 0.94, showing very high survey reliability (Table 2).

In the final satisfaction survey, 88% of patients reported “very good” or “good” overall satisfaction (question 1). When asked, “Do you have any plans to use the SAP after this study?”, 86% of patients responded, “absolutely yes” or “yes.” Regarding the convenience of using the equipment, 97.6% of patients answered, “very good” or “good” (question 6). When asked, “Did the SAP improve your trust in your medical care?”, 97% of patients responded “absolutely yes” or “yes.” When asked, “Do you think the SAP is a good way to manage serious diseases?” (question 17), 97% of patients responded “absolutely yes” or “yes.” Regarding overall satisfaction with telephone health counseling (question 22), 76% of patients responded “very good.”

The SAP satisfaction survey responses were standardized to determine which factors influenced satisfaction level, with a lower total score indicating higher satisfaction. The correlations between satisfaction and age, sex, distance from hospital to residence, smoking history, lung cancer

| Variable | Category | Total satisfaction score | p-value |
|----------|----------|--------------------------|---------|
| Age (yr) | <30      | 35.65 (33.04–38.26)      | 0.398   |
|          | 30–39    | 24.34 (24.34–24.34)      |         |
|          | 40–49    | 22.39 (21.73–23.04)      |         |
|          | 50–59    | 20.00 (18.26–40.43)      |         |
|          | ≥60      | 24.13 (18.26–40.00)      |         |
| Sex      | Male     | 25.21 (18.26–40.00)      | 0.410   |
|          | Female   | 23.04 (18.26–40.43)      |         |
| Distance from hospital to residence (km) | <20 | 23.04 (18.26–40.43) | 0.013 |
|          | 20–80    | 28.26 (18.26–40.00)      |         |
|          | >80      | 18.26 (18.26–23.91)      |         |
| Smoking status | None | 23.91 (18.26–40.43) | 0.599 |
|          | Ex-smoker | 21.73 (18.26–26.08) |         |
|          | Current  | 25.65 (18.26–40.00)      |         |
| Stage    | 1        | 23.04 (18.26–38.69)      | 0.214   |
|          | 2        | 21.73 (18.26–33.91)      |         |
|          | 3        | 20.00 (18.26–40.43)      |         |
|          | 4        | 21.95 (20.00–23.91)      |         |
| Comorbidities | None | 24.78 (18.26–40.43) | 0.126 |
|          | Hypertension | 22.17 (18.26–40.00) |         |
|          | Diabetes | 18.26 (18.26–20.43)      |         |

Values are presented as median (min–max). Lower scores reflect higher satisfaction.
stage, and comorbidities were investigated. Only distance from the hospital to the patient’s residence was found to be significantly correlated with satisfaction level (p=0.013) (Table 3).

In the EORTC QLQ-C30 survey, for the functional scale, significant improvements were observed in all subsections (p<0.05). However, no significant improvement was seen in the symptom scale. Similarly, no significant differences were observed in the EORTC QLQ-LC13 survey results (Table 4).

No significant difference was observed in upper extremity muscle strength, but significant improvements in lower extremity muscle strength were observed, with repetitions increasing from 18 to 22 for the 30-second chair stand test (p=0.012). A significant improvement was also noted in walking distance in the 2-minute walk test (from 185.7 to 195.0 m; p=0.028) (Table 5).

### Discussion

In this study, we found that the SAP can be useful in lung cancer patients. The participants had a high level of overall satisfaction with the SAP, and these results were reflected in their intentions of future use. Five participants (10%) dropped out due to the stress of adhering to the protocol of the SAP. However, 97% of those who completed the study were satisfied with the convenient use of the equipment. This suggests that patients were more adaptable to smartphones and electronic devices than expected, potentially for 3 reasons. First, only patients with smartphones were selected for the study. Second, the average age of the patients in the study was 58 years, indicating that relatively young patients participated in the study. Third, the research team collaborated extensively to manage the patients. The counseling center provided weekly telephone counseling.

### Table 4. Changes in quality of life before and after the Smart After-Care Program

| Variable            | Before          | After           | p-value |
|---------------------|-----------------|-----------------|---------|
| EORTC QLQ-C30       |                 |                 |         |
| Global health status| 66.7 (16.7–100.0)| 83.3 (33.3–100.0)| <0.001 |
| Physical functioning| 80.0 (20.0–100.0)| 86.7 (60.0–100.0)| 0.017  |
| Role functioning    | 83.3 (0–100.0)  | 83.3 (33.3–100.0)| 0.030  |
| Emotional functioning| 75.0 (16.7–100.0)| 91.7 (41.7–100.0)| <0.001 |
| Cognitive functioning| 83.3 (33.3–100.0)| 83.3 (33.3–100.0)| <0.001 |
| Social functioning  | 83.3 (0–100.0)  | 100.0 (33.3–100.0)| 0.022  |
| Fatigue             | 33.3 (0–100.0)  | 22.2 (0–66.7)   | 1.000  |
| Nausea/vomiting     | 0 (0–66.7)      | 0 (0–50.0)      | 0.626  |
| Pain                | 16.7 (0–100.0)  | 0 (0–83.3)      | 0.998  |
| Dyspnea             | 33.3 (0–100.0)  | 0 (0–66.7)      | 1.000  |
| Insomnia            | 33.3 (0–100.0)  | 0 (0–100.0)     | 0.916  |
| Appetite            | 0 (0–100.0)     | 0 (0–100.0)     | 0.989  |
| Constipation        | 0 (0–100.0)     | 0 (0–66.7)      | 1.000  |
| Diarrhea            | 0 (0–100.0)     | 0 (0–66.7)      | 0.926  |
| Financial problem   | 0 (0–100.0)     | 0 (0–66.7)      | 0.994  |
| Total score         | 633.2 (538.3–838.6)| 620.1 (521.0–785.5)| 0.995  |
| EORTC QLQ-L13       |                 |                 |         |
| Cough               | 33.3 (0–100.0)  | 33.3 (0–66.7)   | 0.926  |
| Hemoptysis          | 0 (0–33.3)      | 0 (0–0)         | 1.000  |
| Dyspnea             | 22.2 (0–77.8)   | 11.1 (0–66.7)   | 0.989  |
| Mouth               | 0 (0–66.7)      | 0 (0–66.7)      | 0.650  |
| Dysphagia           | 0 (0–66.7)      | 0 (0–33.3)      | 0.938  |
| Neupathy            | 0 (0–66.7)      | 0 (0–100.0)     | 0.930  |
| Alopecia            | 0 (0–66.7)      | 0 (0–100.0)     | 0.612  |
| Pain, chest         | 0 (0–100)       | 0 (0–66.7)      | 0.983  |
| Pain, arm           | 33.3 (0–100.0)  | 33.3 (0–100.0)  | 0.995  |
| Pain, other         | 16.65 (0–100.0) | 0 (0–66.7)      | 0.933  |
| Total score         | 177.7 (0–466.9) | 111.0 (0–600.2) | 1.000  |

Values are presented as median (min–max). Higher scores reflect higher quality of life. p-values for differences were determined using the Wilcoxon signed-rank test (1-sided, H1: before<after).

EORTC, European Organization for Research and Treatment of Cancer; EORTC QLQ-C30, EORTC Core Quality of Life Questionnaire; EORTC QLQ-L13, EORTC Quality of Life Questionnaire-Lung Cancer 13.
In lung cancer patients, aerobic exercise reduces postoperative complications and helps patients recover quickly [20,21]. Furthermore, enhanced physical activity is related to increased cancer survival and decreased cancer recurrence rate [22]. Therefore, we emphasized personalized exercise and respiratory rehabilitation in this study. As a result, significant improvements in lower extremity muscle strength and 2-minute walking distance were observed. As a cardiorespiratory endurance assessment for lung resection surgery, a 6-minute walk test has been cited the most frequently [23]. However, several previous studies have reported that a 2-minute walk test may be safer and more useful for measuring cardiorespiratory endurance in patients with impaired bodily function, such as those with Parkinson disease or older adults [24]. Considering the disease characteristics and lung function of the participants, we adopted a 2-minute walk test. No adverse events were noted during the 2-minute walk tests, and significant improvement was demonstrated by the test. Meanwhile, no significant change occurred in upper extremity muscle strength. We attribute this result to the difficulty in completing upper body exercises because of pain in the chest wound area or limited shoulder joint movement among the patients who had undergone thoracic surgery. In the future, given these characteristics of patients after lung cancer surgery, a program focusing on improving flexibility would be preferable to one focused on muscle strength.

After lung cancer treatment, many survivors have poor QOL. Yun et al. [25] analyzed the correlation between QOL and mortality in patients with complete recovery after lung cancer surgery. They found that more severe decreases in QOL had greater impacts on mortality; thus, they argued that a systematic care program should exist to evaluate and manage QOL. According to these authors, this program should include exercise and diet management, along with monitoring of disease recurrence after lung cancer treatment. From this perspective, SAP is a potential option. Conventionally, management of patients with lung cancer surgery involves only outpatient follow-up through chest computed tomography every 3–6 months. Our aim was to improve the QOL of lung cancer patients more actively through the SAP and, if successful, to determine how it helps improve QOL. Among the QOL indicators, all functional scales improved significantly, potentially due to the systematic management of the SAP. However, the symptom scales did not change significantly, presumably due to the relatively small proportion of patients who had undergone surgery within 2 months of study initiation (n=12) or who were undergoing chemotherapy (n=4). In other words, we believe that 26 patients (62%) were enrolled in the study at a stage when acute symptoms had already abated. In the future, if a randomized controlled study is conducted among patients with acute symptoms, the ability of the SAP to contribute to reducing symptoms can be determined more clearly.

The distance from hospital to the patient’s residence was the only independent factor significantly correlated with satisfaction. For the statistical analysis, we divided the distance into 3 categories (less than 20 km, between 20 km and 80 km, and more than 80 km). Distances less than 20 km were considered to indicate good access to the hospital, while distances greater than 80 km indicated a high level of burden in traveling back and forth in a day. Satisfaction was significantly higher among patients who resided more than 80 km from the hospital than among those who lived closer (p=0.013). While telemedicine like SAP does not involve in-person visits or examinations, participating patients can communicate with the medical team more frequently than with conventional services. When a patient’s condition is unstable, the SAP is thought to assist in taking appropriate first-aid measures and is expected to reduce unnecessary hospital visits due to simple anxiety.

This study has some limitations. As a pilot study, the number of participants was small, and the study was de-

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**Table 5. Changes in muscle strength and cardiorespiratory endurance before and after the Smart After-Care Program**

| Variable | Before | After | p-value |
|----------|--------|-------|---------|
| Upper arm, left<sup>a</sup> (kg) | 25.5 (15.9–50.3) | 25.0 (15.7–48.7) | 0.461 |
| Upper arm, right<sup>b</sup> (kg) | 27.8 (11.0–52.4) | 26.0 (7.4–50.5) | 0.227 |
| Lower extremity<sup>c</sup> (repetitions) | 18.0 (8.0–35.0) | 22.0 (8.0–116.0) | 0.012 |
| 2-minute walk test (m) | 185.7 (90.0–255.0) | 195.0 (99.0–231.5) | 0.028 |

Values are presented as median (min–max). p-values for differences were determined using the Wilcoxon signed-rank test (1-sided, H1: before<after).

<sup>a</sup> Muscle strength of the left upper arm.
<sup>b</sup> Muscle strength of the right upper arm.
<sup>c</sup> Muscle strength of lower extremity, measured as repetitions of chair stand up/sit down within 30 seconds.
signed for a single arm. A large-scale, prospective randomized controlled study with more homogeneous lung cancer patients will be needed to confirm whether the SAP actually helped improve the QOL and physical ability. Additionally, caution is required in interpreting the results because the effectiveness of the SAP may have varied depending on the treatment modality, the extent of pulmonary resection, stage of cancer, or the timing of study participation.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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