The health economic effects of an imaging technology–based telemedicine system for rural neuro-emergency patient care

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OBJECTIVE  “Join,” an imaging technology–based telemedicine system, allows simultaneous radiological information sharing between physically remote institutions, virtually connecting advanced medical institutions and rural hospitals. This study aimed to elucidate the health economics effect of Join for neurological telemedicine in rural areas in Hokkaido, Japan.

METHODS Information concerning 189 requests for patient transfer from Furano Kyokai Hospital, a regional rural hospital, to Asahikawa Medical University Hospital (AMUH), an advanced academic medical institution, was retrospectively collected. The Join system was established between Furano Kyokai Hospital and AMUH in February 2019. Data collected from patients between April 2017 and December 2018 were included in the non-Join group, and those collected between February 2019 and October 2020 were included in the Join group. Clinical variables, reasons for patient transfer requests, duration of hospital stay, and medical costs per patient were analyzed between these two groups. Furthermore, clinical characteristics were compared between patients who were transferred and not transferred based on Join.

RESULTS More patients were discharged < 7 days after transfer to AMUH in the non-Join group compared with the Join group (p = 0.02). When focusing on the Join group, more patients who were not transferred were discharged < 1 week (p < 0.01). On the other hand, more patients required surgery (p = 0.01) when transferred. The ratio of patients whose medical cost was < USD5000 substantially decreased, from 33% for the non-Join group to 13% for the Join group.

CONCLUSIONS An imaging technology–based telemedicine system, Join, contributed to reducing unnecessary neuro-emergency patient transfer in a remote rural area, and telemedicine with an integrated smartphone system allowed medical personnel to effectively triage at a distance neuro-emergency patients requiring advanced tertiary care.

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KEYWORDS telemedicine system; neuro-emergency; health system economics

HOKKAIDO is a Japanese prefecture that occupies 22% of the nation’s territory, a size equivalent to the territorial size of Ireland. On the other hand, only 4.2% of the Japanese population live in Hokkaido, making it difficult to supply enough specialized medical personnel for its rural areas. This difficulty is particularly pronounced in neurology and neurosurgery because these disciplines require highly specialized personnel and equipment for accurate diagnosis and treatment. As a result, rural hospitals tend to request the transfer of patients with neurological conditions to distant advanced medical institutions. However, patients with only minor medical problems are discharged the day after transfer, thus posing unnecessary burdens on medical personnel and the infrastructure of advanced medical institutions.

Our institution, one of the advanced academic hospi-
In Hokkaido covering 800,000 inhabitants, started to adopt an imaging technology–based telemedicine system to address the issue mentioned above. The system consists of a smartphone application called “Join” (Allm, Inc.; FDA Listing Number: D245938, Medical device approval number in Japan: 227AOBZX00007Z00, https://www.allm.net/wp-content/uploads/Join_Brochure_EN.pdf) that is capable of directly transferring Digital Imaging and Communications in Medicine (DICOM) images from a local Picture Archiving and Communication System (PACS) server to the target smartphone via high-speed cellular networks such as LTE or 4G (Fig. 1). This technology allows simultaneous radiological information sharing between physically remote institutions, virtually connecting advanced medical institutions and rural hospitals. Unlike freely available instant messaging systems on smartphones, Join allows the user to select and view all the shared DICOM images as if viewing them on a PACS client under a secure environment without leaving any trace of the patient’s personal information in the target smartphone. Specialized medical personnel can instantly determine whether it is necessary to transfer the patient in question based on the shared radiological information, leading to proper triaging of patients to transfer. Previous studies focused mainly on using Join in neurological emergencies such as stroke care. However, the use of Join has not been studied from a medical economy point of view as a neurological telemedicine tool connecting advanced medical institutions and rural hospitals. This study aimed to elucidate the health economics effect of Join for neurological telemedicine in rural areas in Japan.

Methods

Cohort Design

The local institutional review board approved the use of clinical data for this research. Information concerning 189 requests for patient transfer from Furano Kyokai Hospital (FKH) to Asahikawa Medical University Hospital (AMUH) between April 2017 and December 2018 and between February 2019 and October 2020 was retrospectively collected. Data collected during January 2019 were excluded, because Join was in the beta phase during this period. FKH is in Furano, a rural region in Hokkaido of 601 km² encompassing a population of 22,000, with no full-time, board-certified neurosurgeon working in the region. On the other hand, AMUH is an advanced academic medical institution situated in the center of Hokkaido, providing 24/7 neurological and neurosurgical service. The two hospitals are located 50 km apart (Fig. 2A). Patient consultations between the two hospitals were done by telephone calls before introducing Join. The Join system was established between FKH and AMUH in February 2019. Patient consultation workflow after introducing Join involved the following: 1) patient consultation request by telephone calls exchanging information on basic clinical background of the patient; 2) key DICOM image exchange via Join; and 3) determination whether to keep the patient at FKH or to initiate patient transfer procedure to AMUH. Data collected from patients between April 2017 and December 2018 were included in the non-Join group, and data collected between February 2019 and October 2020 were included in the Join group (Fig. 2B). Thus, information on each group of patients was collected over 21 months. No system failure involving Join occurred during this period. Days of hospital stay were determined as the time from transfer to discharge at AMUH.

Clinical Variables

The clinical characteristics of the entire cohort are shown in Table 1. Patients were classified as suffering from a cerebral ischemic disease such as cerebral infarction and transient ischemic attack (TIA) or a cerebral hemorrhagic disease such as cerebral hemorrhage and subarachnoid hemorrhage (SAH) or trauma, and/or other conditions. Other conditions included brain tumors, convulsions, spinal stenosis, dizziness, and no neurological findings. Treatment outcome was measured by the modified Rankin Scale (mRS) score at discharge. Patient deaths and surgical cases were counted for those who died or underwent surgery during hospitalization at AMUH. Medical costs were categorized into 5 groups for every USD5000 (USD1 = 100 yen). One patient was not included when calculating medical costs because this individual was repeatedly hospitalized in AMUH within 24 hours, which hampered an accurate medical cost calculation.
Sato et al.
Neurosurg Focus  Volume 52 • June 2022

Statistical Analysis

Variables in Table 1 are expressed as the mean ± inter-quartile range (IQR) 25th–75th percentile or number and percentage of patients. Statistical analysis was performed using Pearson’s chi-square test or Fisher’s exact test to evaluate correlations between categorical variables. The Kolmogorov-Smirnov test was used to assess the data distribution of continuous variables. The Student t-test was used to compare normally distributed continuous variables, and the Mann-Whitney U-test was used for nonnormally distributed variables. All statistical analyses were performed using EZR software.

Results

Overall Cohort Characteristics

Table 1 and Fig. 2B summarize the analyzed cohort’s patients’ characteristics. There were 59 men and 40 women, with a mean age of 73 (range 63–95) years for the non-Join group and 41 men and 49 women, mean age 76 (range 70–95) years, for the Join group. There were no statistically significant differences between the two groups regarding age and sex, but there were more surgical cases for the non-Join group (p < 0.01). FKH transferred 23 patients during the Join period and 11 patients during the non-Join period to other hospitals for neuro-emergency care. A total of 44 cases were not transported to AMUH during the Join period (Table 2 and Fig. 2B).

Comparison of Transferred Patients During the Non-Join and Join Periods

Table 3 compares the clinical characteristics of the patients transferred to AMUH between the non-Join and Join periods. There were no differences in age, sex, mRS score 0–2, death after the transfer, surgery cases, and transfer causes. However, numbers of patients with hospital stays < 1 week were significantly different between the two groups. More patients were discharged < 7 days after transfer to AMUH in the non-Join group (p = 0.02) (Table 3 and Fig. 3A).

Comparison of Transferred and Nontransferred Cases in the Join Group

Table 4 compares the clinical characteristics between transferred and nontransferred cases in the Join group. There were no differences in age, sex, and causes of transfer request such as infarction and TIA, cerebral hemorrhage, SAH, and trauma. There were significantly more deaths in the nontransferred group (p = 0.01). Significantly more patients were discharged < 1 week in the nontransferred group (p < 0.01). On the other hand, more patients required surgery (p = 0.01) in the transferred group.

TABLE 1. Characteristics of 189 patients whose transfer was requested

| Characteristic                  | Non-Join | Join | p Value |
|--------------------------------|----------|------|---------|
| Mean age in yrs (IQR)          | 73 (63–95) | 76 (70–95) | 0.16    |
| Sex (M/F)                      | 59:40    | 41:49 | 0.06    |
| Cause of hospitalization       |          |      |         |
| Surgery cases                  | 23       | 7    | <0.01*  |
| Infarction or TIA              | 31       | 35   | 0.29    |
| Cerebral hemorrhage            | 26       | 19   | 0.49    |
| SAH                            | 7        | 3    | 0.34    |
| Trauma                         | 22       | 12   | 0.13    |
| Other                          | 11       | 20   | 0.05*   |

* Variables showing significant differences.
were more patients requiring hospitalization due to other causes in the nontransferred group \((p < 0.01)\).

### The Medical Cost Difference of Transferred Cases Between the Non-Join and Join Periods

Figure 4 compares medical costs of patients transferred from FKH to AMUH between the non-Join and Join periods, each categorized by increments of USD5000. The ratio of patients whose medical cost was < USD5000 substantially decreased from 33% for the non-Join group to 13% for the Join group. On the other hand, cases that cost between USD5000 and < USD10,000 compensated for the loss, and the portion of cases that cost ≥ USD10,000 stayed approximately the same after introducing Join.

### Discussion

Recent developments in digital communication technology have been remarkable, and telemedicine enables cost savings in neurological emergencies. These technologies allow doctors to evaluate detailed medical images on smartphones and remotely make an instant and accurate diagnosis. However, there are not many reports on the use of technologies such as smartphone applications in neuro-emergency care. The smartphone application Join is one of these technologies, mainly in acute stroke care.

### TABLE 2. Cases not transported from FKH to AMUH

| Transport Data                                | No. of Pts |
|-----------------------------------------------|------------|
| Cases not transported based on Join telemedicine app | 44         |
| Cases transported to other hospitals          | 34         |
| Join period                                   | 23         |
| Before Join period (non-Join)                 | 11         |

\(\text{Pts} = \text{patients}\).

The primary purpose of its use is to shorten the time from the first contact with medical personnel to treatment. The primary purpose of its use is to shorten the time from the first contact with medical personnel to treatment.

On the other hand, this technology could be used differently as telemedicine technology in rural areas. Rural hospitals cannot necessarily afford to employ specialists; thus, even mild cases are transferred to a large hospital. Such an inefficient medical system will exhaust medical personnel in both rural and large hospitals. Furthermore, one can argue that the current system is also inefficient from an economic point of view. Our institution started to use Join to solve this problem, and the present study attempted to prove the usefulness of Join for emergency teletriage and telemedicine in rural areas of Hokkaido. The decrease in the number of patients with short hospital stays and with medical costs of < USD5000 indicates that Join reduced transfer of mild cases from a rural hospital to a large medical center (Figs. 3A and 4). The efficiency of patient triage using Join was further supported by the fact that more patients were discharged < 1 week when a decision of nontransfer was made based on Join (Fig. 3B). The fact that there were significantly more surgical cases during the non-Join period also implies that the treatment strategy was more aggressive than during the Join period (Table 1). This phenomenon is probably due to the fact that all patients requested for transfer were transferred and admitted to the advanced academic medical institution, resulting in more surgeries.

The analysis in Table 4 also shows that there were more deaths in the nontransfer group. This phenomenon implies that untreated cases were left within the local rural hospital, avoiding unnecessary transfer of patients along with their families. We consider this trend crucial from a social perspective. Whereas patients and their families expect to receive meaningful advanced treatments at distant academic institutions, they also hope to stay within their local region when suffering from mild or untreatable conditions. In the present study, the number of cases requiring transfer as far as 50 km one way was reduced by Join.

### TABLE 4. Comparison of transferred and nontransferred patients during the Join period

|                           | Transferred, \(n = 46\) | Nontransferred, \(n = 44\) | \(p\) Value |
|---------------------------|--------------------------|-----------------------------|-------------|
| Mean age in yrs (IQR)     | 78 (70–84)               | 81 (72–86)                  | 0.49        |
| Female sex                | 23 (50%)                 | 26 (59%)                    | 0.51        |
| Death after transfer      | 2 (4%)                   | 11 (25%)                    | 0.01*       |
| Hospital stay < 1 wk      | 3 (7%)                   | 22 (50%)                    | <0.01*      |
| Surgery cases             | 7 (15%)                  | 0 (0%)                      | 0.01*       |
| Cause of hospitalization  |                          |                             |             |
| Infarction or TIA         | 20 (43%)                 | 15 (34%)                    | 0.49        |
| Cerebral hemorrhage       | 12 (26%)                 | 7 (16%)                     | 0.36        |
| SAH                       | 3 (7%)                   | 0 (0%)                      | 0.24        |
| Trauma                    | 8 (17%)                  | 4 (9%)                      | 0.40        |
| Other                     | 3 (7%)                   | 17 (39%)                    | <0.01*      |

Unless otherwise indicated, values are expressed as the number of patients (%). * Variables showing significant differences.
From a hospital administrative perspective, transferring patients with mild or untreatable conditions is inefficient and unprofitable; thus, proper triage is necessary. Human resources such as doctors and nurses will be forced to engage in patient care that does not necessarily require skills or infrastructure that only academic medical centers can provide. We were able to show that telemedicine systems such as Join can resolve this issue, particularly in fields that require advanced skills such as neurology and neurosurgery.

We believe that cost reduction by telemedicine has been the focus of attention in recent years. Telemedicine support in neuro-emergency cases has already been shown to reduce per-patient costs. Furthermore, the usefulness of remote diagnostic imaging has also been demonstrated, and many cost-reduction effects have been shown even in chronic medical care. In addition to previous studies, the current research suggests that telemedicine can appropriately triage patient transfer between hospitals, enhance efficiency, and reduce the unnecessary workload of advanced medical institutions.

Several careful considerations should also be mentioned. Although we did not encounter any system failure during the period analyzed, a backup operation plan should be prepared to deal with such a situation, and a workflow via traditional patient consultation methods should be established between rural hospitals and academic medical centers. Furthermore, the proposed telemedicine system has a potential drawback, as can be seen by the higher number of patients transferred from FKH to hospitals other than AMUH during the Join period than during the non-Join period (11 during non-Join vs 23 during Join period). This implies that the local doctors at FKH may have been reluctant to treat neuro-emergency cases in their hospitals. A larger-scale analysis will be required to determine the negative impact of using telemedicine systems between rural hospitals and academic medical centers.

Conclusions
An imaging technology–based telemedicine system,
Join, substantially reduced the ratio of patients whose medical cost was < USD5000 and contributed to reducing unnecessary neuro-emergency patient transfer in a remote rural area. We were able to demonstrate that patients with neuro-emergency status not requiring transfer were kept close to home for mild care—or in cases of death, close to family for closure—by using telemedicine with an integrated smartphone system. On the other hand, patients at a distance who required advanced tertiary care were effectively triaged and received a higher level of care.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Sato, T Osanai, Ogasawara. Acquisition of data: Sato, Tani, H Osanai, Ogasawara. Analysis and interpretation of data: Kinoshita, Sato, Tani. Drafting the article: Kinoshita, Sato, Ogasawara. Critically revising the article: Kinoshita, Tani, Kimura, T Osanai, Ogasawara. Reviewed submitted version of manuscript: Kinoshita, Sato, Ogasawara. Statistical analysis: Sato. Administrative/technical/material support: Kinoshita, Ogasawara. Study supervision: Kinoshita.

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