Using Telemedicine and Drones to Keep Remote Island Communities Safe and Secure: A Concept Note for the Launch of the Smart Island Promotion Project in Awashima Adopted by the Ministry of Land, Infrastructure, Transport and Tourism

Prof. Kazuhiro Hara

Emeritus Professor at Kagawa University.

Specially Appointed Professor of Seto Inland Sea Regional Research Center, Kagawa University

President of e-Health Care Innovation in Kagawa (e-HCIK)

President of Japanese Telemedicine and Telecare Association

Introduction

Kagawa, Japan's smallest prefecture with 24 populated islands in the Seto Inland Sea, has great difficulty delivering healthcare to remote islands. The prefecture as a whole boasts robust healthcare infrastructure, well served by medical facilities including Kagawa University Hospital.

However, the 24 populated islands are underserved; only 10 islands have clinics, and the others are left without any healthcare facilities. The islands with clinics also have difficulty finding full-time physicians; therefore, most of them are served by physicians sent from hospitals in the mainland of Kagawa only on specific days of the week, leaving residents with limited access to healthcare, especially on weekends and at night.

In order to reduce these healthcare disparities within the prefecture, Kagawa Medical Information eXchange[A1] (K-MIX) was launched in 2003 and upgraded into K-MIX+ in 2013. This medical network provides participating healthcare facilities with access to electronic patient records kept at core hospitals (16 hospitals). Moreover, Kagawa Prefecture, designated as a Comprehensive Special Zone for Medical and Welfare Services with funding for the Project for Creating Safe Communities with Kagawa Medical Information eXchange (K-MIX)[A2] by the Government of Japan in 2011, developed an Olive Nurse System to promote visiting and in-home care, though due to the rigorous requirements for becoming an Olive Nurse, these services are still struggling to reach remote islands. Thus, telemedicine was not as widely adopted as expected in remote islands even though it should have been most suitable to the situation. This was partly because broadband internet was not widely available but mainly because the local government was not very keen to expand telemedicine.

The first turning point came in 2018, when the use of telemedicine (online consultations) was authorized as an alternative to in-person visits. Coupled with this, the recent COVID-19

pandemic is rapidly laying the groundwork for telemedicine.

This paper, based on my experience at Mitoyo City National Health Insurance Awashima Clinic (for which I work every Monday), presents solutions to healthcare disparities in remote islands. To begin with, it is essential to promote telemedicine and in-home care services and use ICT to promote close collaboration between island clinics and mainland hospitals. In addition, the Olive Nurse system should be deregulated so that many more nurses can participate in the system. Moreover, the Smart Island Promotion Project in Awashima [A3] , adopted this fiscal year by the Ministry of Land, Infrastructure, Transport and Tourism to promote the use of telemedicine and drones, is also sketched out here.

1.Population Transition and Healthcare Services in Remote Islands in Kagawa Prefecture

The population of the 24 populated islands of Kagawa Prefecture decreased over the 15 years from 44,220 in 2000 to 34,123 (77%) in 2015. Among the 24 islands, Shodoshima saw its population fall from 34,572 to 27,927 (81%), Awashima from 415 to 216 (52%), and Shishijima from 44 to 18 (41%). This indicates that islands with smaller population sizes and fewer medical resources had higher decline rates than those with larger population sizes and core hospitals like Shodoshima. (Table 1)

	2000年	2005年	2010年	2015年	%
小豆島	34572	32432	30167	27927	81
男木島	248	189	162	148	60
女木島	244	212	174	136	56
本島	768	605	492	396	52
広島	453	351	281	226	50
栗島	415	349	289	216	52
志々島	44	30	24	18	41
伊吹島	1020	793	590	400	39

離島の人口の推移

(Table 1)　Population trends on remote inhabited islands in Kagawa Prefecture

In Awashima, a privately owned clinic (Dr. Kenjiro Shiotsuki) was opened in the 1960s and operated for about five decades. In 2012, when the clinic was closed, healthcare services were taken over by the Mitoyo Municipal Government, which opened Mitoyo City National Health Insurance Awashima Clinic. (Figures 1 and 2)

(Fig.1) Awashima is located about 4 km offshore of Suda Port in Mitoyo City, Kagawa Prefecture.）

(Fig.2) Awashima Clinic of Mitoyo City National Health Insurance

The new clinic had difficulty finding a full-time physician and therefore had physicians sent from three hospitals in Kanonji District, Mitoyo City: Eiko Hospital (municipally-owned), Iwasaki Hospital (privately-owned), and Matsui Hospital (privately-owned). At the beginning,

the clinic was open four days a week. However, it is now open only two days a week (every Monday and Friday morning and the fourth Monday afternoon of each month) due to the reduced number of physicians.

The population of Awashima fell more than 90% from 70 years ago, down to 201 in March 2020. The population is also rapidly aging, with those 70 and older accounting for 83.8% of the total population.

Awashima Clinic has two nurses, who commute from outside the island (every morning and afternoon from Monday to Friday). When an emergency case occurs while no physician is present, one of the nurses will deal with it under instructions given by a physician on the phone.

As the number of patients served by the clinic also declines year by year (down from 286 in 2014 to 222 in 2019), the clinic could hardly stay in business without funding from the municipality.

Awashima Clinic mainly serves local residents (elderly people), with a few exceptions, such as business and leisure tourists with injuries or fevers, and most of the cases are not emergencies. Still, Awashima Clinic receives emergency cases from time to time, such as cardiac infarction, brain infarction, and serious injuries, and the rapid response to emergency cases remains a serious challenge for the clinic.

Thus, the analysis of healthcare in remote islands should distinguish between two different roles: (1) responses to chronic cases, such as providing daily guidance and prescribing medicines, and (2) responses to acute cases requiring ambulance transport to hospitals outside the island.

1) Responses to chronic cases The main role of physicians at Awashima Clinic is to provide daily guidance and prescribe medicines for patients diagnosed with high blood pressure, diabetes, hyperlipemia, and other chronic diseases by their physicians at mainland hospitals. The clinic's physicians collaborate with physicians at mainland hospitals, consulting them and referring any concerns to them when a patient's condition changes. Meanwhile, some of the patients are told to come to see their physicians at mainland hospitals on a regular basis, which places a rather heavy burden, especially on elderly patients. Many of the ophthalmologic, otorhinolaryngological, and orthopedic patients in the island visit mainland hospitals just to receive eye drops, nose drops, or pain killers.

Apart from the question of medical fees, if patient information is shared between island clinics and mainland hospitals, it can significantly reduce the burden of transport on elderly patients living in remote islands.

As the first step to this end, we are considering introducing a system where Awashima

Clinic will manage the personal health records of chronic patients, with consent from their mainland hospitals, so that the patients in the island can receive their medicines at the clinic and visit their mainland hospitals only when their condition changes or they receive regular checkups.

2) Responses to acute cases requiring ambulance transport Unlike chronic diseases, acute diseases such as angina pectoris, cerebral infarction, and serious injuries, require urgent care because they can be life threatening and directly affect the long-term quality of life. Under the present circumstances, when an acute patient is admitted to the clinic while nurses are on duty, the case will be dealt with by the nurses under instructions given by a physician on the phone or transported by water taxi and ambulance to a core hospital (e.g. Mitoyo General Hospital and Eiko Hospital) if necessary. However, when no nurse is on duty, residents will deal with emergency cases by calling an ambulance by themselves.

2. Patient Information Sharing and Online Consultations Essential to Solving the Abovementioned Problems

As mentioned above, K-MIX was launched in 2003 and upgraded into K-MIX+ in 2013, providing participating healthcare facilities with access to electronic patient records kept at core hospitals. This medical network made Kagawa the most advanced prefecture in terms of telemedicine, but it has not worked well enough to eliminate healthcare disparities in remote islands.

In the meantime, the use of online consultations to examine patients in remote locations via realtime video-conferencing was authorized as an alternative to in-person visits in 2018. Coupled with this, the recent COVID-19 pandemic is rapidly laying the groundwork for telemedicine.

It is expected that once Awashima Clinic is ready to share patient information and provide online consultations, it will be able to deal with not only chronic cases but also acute cases even if no physician is on duty at that moment.

1) Network environment required for telemedicine services

It used to be considered that telemedical systems, including K-MIX, would require broadband connections (fiber optic cables); however, recent mobile networks (4G networks) are found to be fast enough for those systems to work. Moreover, as often reported on television, with a smartphone or tablet, patients can receive online consultations via video-conferencing.

All the equipment clinics require to offer online consultations is a PC, a webcam, a microphone and a speaker for video-conferencing, and a mobile router. The communication

will be more stable if fiber optic cables or 5G networks are installed in the future.

2) Impacts of K-MIX, K-MIX+, and online consultations Telemedicine consists of two totally different parts, electronic patient record networks, such as KMIX and K-MIX+, and online video-conferencing consultations, though both of them are essential to effective practice. While K-MIX and K-MIX+ are mainly intended to provide online access to electronic patient records including CT and MR imaging data at different healthcare facilities, online consultations are virtual outpatient consultations where physicians examine patients in remote locations, give them daily guidance, and prescribe medicines for them by using a computer in the doctor's office to make real-time video calls with the patients, who receive the calls on their smartphone or other mobile device.

Online consultations at Awashima Clinic are offered the other way around as patients receive remote consultations using the video-conferencing system at the clinic while physicians are working at their hospitals outside the island. With nurses in attendance to take the vital signs of patients, such as blood pressure, pulse, body temperature, blood sugar, and oxygen saturation, the clinic can provide a more accurate diagnosis than other facilities offering ordinary online consultations.
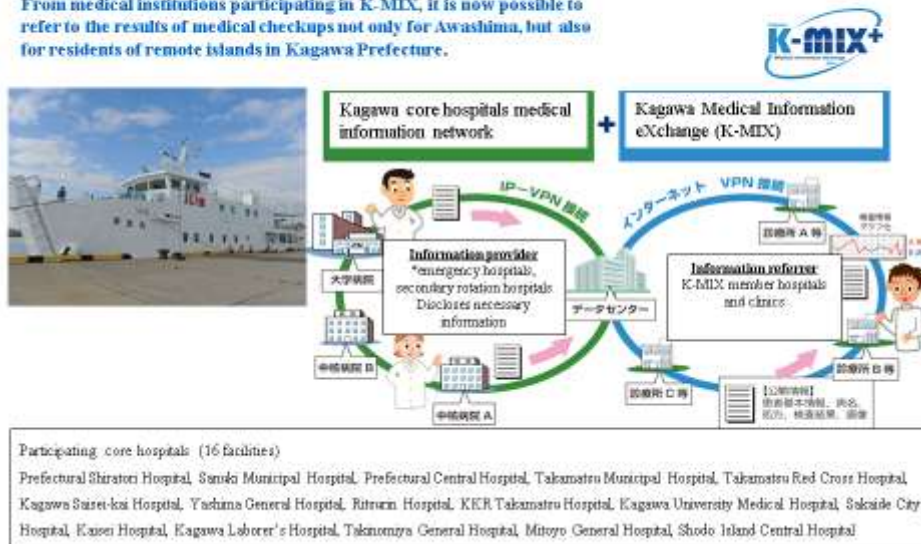
Online consultations must include online medication counseling by pharmacists. Although Awashima Clinic planned to start medication counseling in September 2020, it suddenly changed the plan and started the service earlier on an emergency basis in response to the COVID-19 pandemic. The introduction of online medication counseling has improved telemedicine in the remote island.

3) Use of K-MIX+ to share health checkup results provided by the Saiseimaru Boat Clinic with healthcare facilities

The Saiseimaru is the only boat clinic in Japan, run by Social Welfare Organization Saiseikai Imperial Gift Foundation, Inc. to offer health checkups to residents in islands in the Seto Inland Sea on a regular basis. This checkup includes chest X-ray imaging, stomach cancer testing, 12-lead electrocardiogram, and blood testing and provides important indicators that can be used to examine health conditions during consultations. In the past, checkup results were directly mailed to residents and rarely shared with relevant healthcare facilities. However, the Saiseimaru's checkup results have been stored on the server at Kagawa Saiseikai Hospital, and with support from the local administration and Saiseikai Hospital, the checkup results of people living in Awashima and other islands in Kagawa are now made accessible for the healthcare facilities involved in K-MIX. (Figure 3)

Coordination of health checkup information between medical institutions and the Saiseimaru Boat Clinic by K-MIX+

From medical institutions participating in K-MIX, it is now possible to refer to the results of medical checkups not only for Awashima, but also for residents of remote islands in Kagawa Prefecture.

Participating core hospitals (16 facilities)

Prefectural Shiratori Hospital, Sanuki Municipal Hospital, Prefectural Central Hospital, Takamatsu Municipal Hospital, Takamatsu Red Cross Hospital, Kagawa Saisei-kai Hospital, Yashima General Hospital, Ritsurin Hospital, KKR Takamatsu Hospital, Kagawa University Medical Hospital, Sakaide City Hospital, Kaisei Hospital, Kagawa Laborer's Hospital, Takinomiya General Hospital, Mitoyo General Hospital, Shodo Island Central Hospital

（Fig. 3）Coordination of health checkup information between medical institutions
and the Saiseimaru Boat Clinic by K-MIX+

This has attracted attention not only from the healthcare sector but also from many other sectors as it is the first information sharing system that includes both health checkup information and patient records. Although this is an important step in the process of improving healthcare in remote islands, it was difficult to take in the past due to various institutional barriers. This information sharing system should be further improved in the future by incorporating the medical records of in-home patients and patients admitted to nursing homes as well as other health data of local residents.

3. Further Deregulation and Nationwide Expansion of the Olive Nurse System under the Comprehensive Special Zone Program

Kagawa was designated as a Comprehensive Special Zone for Medical and Welfare Services with funding for the Project for Creating Safe Communities with Kagawa Medical Information eXchange (K-MIX) under the Comprehensive Special Zone Program by the Government of Japan in FY2011. This Special Zone Project aims to eliminate healthcare disparities in remote islands and mountainous areas and create safe communities where all residents can access high-quality healthcare and welfare services by making active use of telemedicine to empower healthcare workers to play a more active role. In particular, the Olive

Nurse System has attracted attention as an innovative system that lifted the prohibition of medical care without personal examinations (the principle of in-person medical care) under Article 20 of the Medical Practitioners' Act to empower trained nurses(Olive Nurses) to practice medicine with no physician in attendance if they share patient information with a physician via realtime video-conferencing.

However, the current certification requirements for Olive Nurses are too strict (they need to get certified as registered nurses and complete e-leaning and practical training on certain skills such as inhome nursing care and ultrasonography) and not suitable to the situation in remote islands or rural areas which need Olive Nurses more than any other regions. Because the Olive Nurse System is an ideal form of telemedicine, given that the use of online consultations has been authorized and the doctor-to-patient-with-nurse (D to P with N) telemedicine is recommended at present, the certification requirements of Olive Nurses should be reduced to achieve better results, which can in turn pave the way to the wide application of the system around Japan. (Figure 4)

Note: Ordinary online consultations are offered by doctors to patients (D to P); however, in the case of Awashima Clinic, online consultations are offered with a nurse in attendance with the patient (it is called "D to P with N" telemedicine). This is considered more desirable because it can improve the accuracy of online examinations and allow nurses to practice medicine as required.
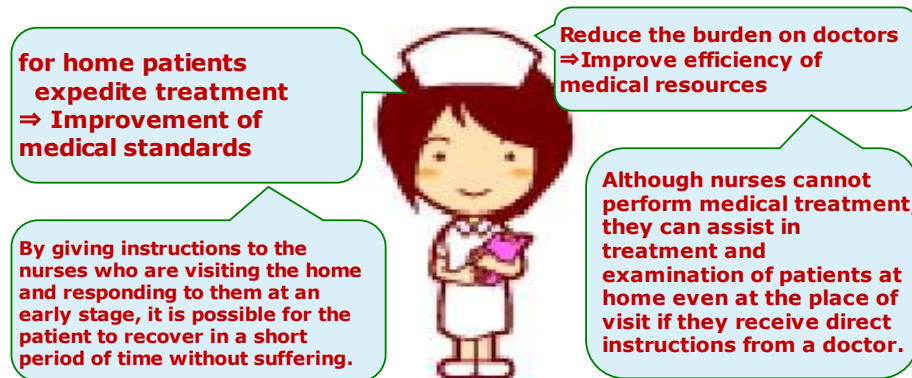
4. ICT-based Home Health Management

Online consultations are not comparable in quality to in-person consultations because videoconferencing keeps physicians from taking the vital signs of patients, such as blood pressure, body temperature, heat rate, and breathing. However, portable medical devices have been recently put into use, allowing patients to take their vital signs in their homes and send the information to their physicians. The use of these devices for health management in remote islands can make it easier to detect early signs of diseases such as myocardial infarction and cerebral infarction. In the future, we will further work to incorporate these data in the Olive Nurse System and online consultations to provide better home health management solutions.

Deregulation in Comprehensive Regional Revitalization Special Zone (Kagawa Comprehensive Medical Welfare Zone)
Number of applications nationwide (358) → Areas designated (26)
Development of reliable City utilizing the Kagawa Telemedicine Network (K-MIX)

Article 20 of the Medical Practitioners Law (principle of face-to-face medical treatment)
Relaxation of the prohibition of non-medical treatment
(1) Promotion of telemedicine (K-MIX) utilizing the "TV conference system"
(2) Upbringing of prefecture-specific "olive nurses" who have undergone a certain amount of training

for home patients expedite treatment ⇒ Improvement of medical standards

Reduce the burden on doctors ⇒Improve efficiency of medical resources

By giving instructions to the nurses who are visiting the home and responding to them at an early stage, it is possible for the patient to recover in a short period of time without suffering.

Although nurses cannot perform medical treatment, they can assist in treatment and examination of patients at home even at the place of visit if they receive direct instructions from a doctor.

（Fig.4） Olive nurse system in the Comprehensive Regional Revitalization Special Zone System

This is an epoch-making system that enables nurses to provide medical treatment even when a doctor is in a remote location by exchanging patient information with a doctor in real time using a video-conferencing system.

5. Applications of Unmanned Drones in Healthcare in Remote Islands

As mentioned above, Awashima Clinic, which reduced the number of outpatient consultation days from four to two per week, has introduced online consultations on a trial basis. This is found to be very helpful and highly appreciated by patients. The remaining problem is that there is no urgent delivery service available in the case of emergencies, such as when a patient develops an acute fever and needs to have their blood tested or when a patient needs a medicine that is out of stock at the clinic. Even if online consultations and online medication counseling can be offered in remote islands without clinics, telemedicine will not work well without the means to deliver medical and pharmaceutical products.

The key to solving this problem is the use of drones. We held seminars on "The Applications of Drones in Telemedicine" and "How to Take Medicines Safely" with an eye toward the future introduction of online medication counseling at Awashima Shinsei University (senior citizens' university in Awashima) three years ago. In addition, we have approached numerous organizations, including the Mitoyo Municipal Government, to promote the use of drones in telemedicine. These efforts have led to the launch of a

demonstration study to validate the usability of drones in telemedicine in Awashima in collaboration with the Seto Inland Sea Regional Research Center of Kagawa University, KAMOMEYA Inc., and Aioi Nissay Dowa Insurance Co., Ltd.

6. Telemedicine and Drone Demonstrations

On July 30, 2020, a drone (single rotor drone) (Figure 5) was flown from the Port of Suda in Takuma-cho, Mitoyo City to the Port of Awashima, four kilometers away, to deliver a package likened to that of medical and pharmaceutical products.

（Fig.5）Drone（single rotor type）

We delivered medical equipment and drugs from Suda Port to Awashima Port, which is 4km offshore one way.

This demonstration was based on a scenario where a resident in Awashima would visit the clinic with heart palpitations and irregular heartbeat. The drone was used to deliver a portable electrocardiograph from the Port of Suda to Awashima Clinic and then send a blood sample back from the island to the Port of Suda in order to provide an accurate diagnosis. Then, because the scenario also assumed that the patient would be diagnosed with atrial fibrillation by a remote physician examining the electrocardiographic waveform data sent on the internet, a DOAC (Eliquis, which helps prevent blood clots from forming) was delivered by drone to the clinic, and a pharmacist in a remote location provided online medication counseling. (Figure 6)

（Fig.6）Remote medication guidance by pharmacists

It is very difficult for residents of remote islands to go to dispensing pharmacies.

The recent deregulation has made it possible to provide remote medication guidance, which is an epoch-making development for the spread of telemedicine.

The test flight was watched and applauded by the fifth-grade students (approx. 70 students) of Takuma Elementary School who visited Awashima on the same day on a field trip (day camp). After the drone landed, we explained telemedicine in remote islands and the transport of medical products by drone to these elementary students ("future scientists"), who listened with great interest. (Figure 7)

(Fig.7) On the same day, elementary school students (about 70 students) were visiting Awashima for field trips.
A scene explaining Telemedicine on a remote island and logistics delivery by drone.

7. FY2020 Smart Island Promotion Project Adopted by the Ministry of Land, Infrastructure, Transport and Tourism

This fiscal year, when we were considering how to keep the above-mentioned efforts going, the Ministry of Land, Infrastructure, Transport and Tourism made a timely announcement that it would invite applications for its Smart Island Promotion Demonstration Research with the aim of solving problems faced by remote islands. We submitted an application on behalf of the Mitoyo Municipal Government, and fortunately, our project was adopted. The Smart Island Promotion Project, funded by the Ministry of Land, Infrastructure, Transport and Tourism, consists of the following three components, as described in detail elsewhere.

1) Develop community transport services using Green Slow Mobility (GSM) in the island Conduct test runs of GSM between the center of the island and the clinic or community to develop community transport services.

2) Develop delivery services using new ICT infrastructure Conduct demonstration tests to develop unmanned land, sea, air transport services for the future by using an unmanned delivery system with drones to deliver medical and pharmaceutical products and foods.

Validate the most suitable communication infrastructure for remote islands, including the

possibility of using real-time weather solutions required for out-of-sight flights to provide information in the case of natural disasters.

3) Develop a new ICT-based healthcare system

Establish a telemedicine system for remote islands to offer online consultations, including medication counseling, with physicians at mainland hospitals who communicate with and examine patients via the internet when no physician is in the island clinic so as to develop a healthcare system for both local residents and tourists.

8. Make the Sea around Awashima a Sanctuary for Drones

Although the applications of drones have been widely validated in Japan, we believe that Awashima is the most suitable site to test the applications of drones in remote islands. Therefore, we are working to make Awashima a sanctuary for drones.

The reasons why Awashima is the most suitable site to test the applications of drones include:

・The island is relatively close to the mainland, located only four kilometers off the coast;

・There are no international flight routes, railroads, or roads that could interfere with the flight of drones;

・In Awashima, unlike other sites in Japan, drones fly over the sea, and therefore it is unlikely to cause serious damage when a drone crashes;

・Other sites are mostly covered by land and therefore accessible by car or on foot (drones are not necessary);

・As a remote island, Awashima is accessible only by boat or plane;

・Awashima can be used as a site to test not only aerial drones but also water drones; □ Awashima is in the Setouchi Climate Zone, characterized by little rainfall and mild winds throughout the year;

・The sea is bordered by the Shonai Peninsula and Awashima and Shishijima Islands and very calm with little traffic;

・With Mount Shiude (also known as Mount Shiunde; 352 meters above sea level) in the Shonai Peninsula and Mount Jono (222 meters above sea level) in Awashima, the site can be used for mountain test flights;

・With little traffic, Awashima is suitable for autonomous driving testing;

・The Shonai Peninsula has a suitable test site for drones; □ With the Takuma campus of Kagawa Technical College (formerly known as Takuma Radio Technical College) in its vicinity, Awashima plays an important role in human resource development in fields such as the radio navigation of drones; and

・The local residents, fisheries association, and municipality are fully aware of the

importance of drones.

9. Applications of the Telemedicine and Drone Technology Validated in Awashima in the Case of Shikoku Nankai Trough Earthquakes

We expect that the telemedicine and drone technology validated in Awashima can be used not only in daily life in Kagawa but also in emergencies such as Shikoku Nankai Trough Earthquakes.

This is because:

・The Faculty of Medicine of Kagawa University can be used as a medical base when a Shikoku Nankai Trough Earthquake occurs because the building is located inland, standing on solid ground and remote from the risk of tsunami; □ Kagawa University is home to the Institute of Education, Research and Regional Cooperation for Crisis Management Shikoku;

・The Faculty of Medicine of Kagawa University is directly connected by highways to major cities around Shikoku; and

・ The 14th Brigade of the Japan Ground Self-Defense Force responsible for disaster relief is based in Zentsuji City.

Therefore, drone technology can be used to deliver telemedicine services and distribute medical and pharmaceutical products to isolated people in the case of natural disasters such as Nankai Trough Earthquakes.

Conclusion

This paper presents healthcare problems faced by remote islands based on my experience at Awashima Clinic. Kagawa is attracting attention from around Japan as a prefecture with the country's longest history of telemedicine and as a Comprehensive Special Zone with K-MIX. In order to solve healthcare problems in remote islands, it is essential to introduce remote consultations and drones and deregulate the Olive Nurse system. In the future, we will further work to improve healthcare in remote islands and rural areas around Japan by developing Awashima as a demonstration site for telemedicine services and drones and overcoming social and technical challenges through the Smart Island Promotion Project recently adopted by the Ministry of Land, Infrastructure, Transport and Tourism.