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Original Article

World's first telepathology experiments employing WINDS ultra-high-speed internet satellite, nicknamed "KIZUNA"

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Abstract

Background: Recent advances in information technology have allowed the development of a telepathology system involving high-speed transfer of high-volume histological figures via fiber optic landlines. However, at present there are geographical limits to landlines. The Japan Aerospace Exploration Agency (JAXA) has developed the "Kizuna" ultra-high speed internet satellite and has pursued its various applications. In this study we experimented with telepathology in collaboration with JAXA using Kizuna. To measure the functionality of the Wideband InterNet working engineering test and Demonstration Satellite (WINDS) ultra-high speed internet satellite in remote pathological diagnosis and consultation, we examined the adequate data transfer speed and stability to conduct telepathology (both diagnosis and conferencing) with functionality, and ease similar or equal to telepathology using fiber-optic landlines. **Materials and Methods:** We performed experiments for 2 years. In year 1, we tested the usability of the WINDS for telepathology with real-time video and virtual slide systems. These are state-of-the-art technologies requiring massive volumes of data transfer. In year 2, we tested the usability of the WINDS for three-way teleconferencing with virtual slides. Facilities in Iwate (northern Japan), Tokyo, and Okinawa were connected via the WINDS and voice conferenced while remotely examining and manipulating virtual slides. **Results:** Network function parameters measured using ping and Iperf were within acceptable limits. However; stage movement, zoom, and conversation suffered a lag of approximately 0.8 s when using real-time video, and a delay of 60-90 s was experienced when accessing the first virtual slide in a session. No significant lag or inconvenience was experienced during diagnosis and conferencing, and the results were satisfactory. Our hypothesis was confirmed for both remote diagnosis using real-time video and virtual slide systems, and also for teleconferencing using virtual slide systems with voice functionality. **Conclusions:** Our results demonstrate the feasibility of ultra-high-speed internet satellite networks for use in telepathology. Because communications satellites have less geographical and infrastructural requirements than landlines, ultra-high-speed internet satellite telepathology represents a major step toward alleviating regional disparity in the quality of medical care.

Key words: KIZUNA (絆), optical fiber, real-time video system, telepathology, ultra-high-speed internet satellite, virtual slide system

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INTRODUCTION

Telepathology (remote pathological diagnosis system using IT equipment) was first implemented in the early 1980s,[1] and quickly spread around the world.[2-5] In Northern Europe, it connected far northern hospitals with urban facilities. Likewise, hospitals in mountainous regions of Germany and Switzerland were connected with urban hospitals by telepathology systems.[6] In the United States, telepathology was applied to connect larger hospitals with their branches.[7,8] Telepathology has numerous applications, including consultation, intraoperative diagnosis, distance education, and conferencing. In Japan, where there are only 14 pathologists per 100,000 people and many hospitals do not have a pathologist on staff, the primary use of telepathology is overwhelmingly intraoperative remote diagnosis. This usage has received governmental support as a method to alleviate regional disparity in medical care. For this reason, great effort has been made to disseminate virtual slides.[9,10] Telepathology was initially adopted in Japan in the early 1990s. Since this time, technological advances have transformed telepathology. Analog lines were used at first.[11] Now, digital lines are used for static robotic telepathology, and fiber-optic lines transfer real-time high-definition video and virtual slide data.[12,13] Because the diagnosing pathologist can select and move the microscope's stage remotely, as well as adjust both zoom and focus using real-time high-definition video, these new technologies allow most quick diagnoses to be completed within 10 min, provided that the client and diagnostic facilities are connected by fiber-optic network. This means that telepathology can now respond to the need for intraoperative additional resection, making it almost identical to onsite pathological diagnosis at facilities with a full-time staff pathologist. The same conditions are necessary for virtual slides, which are rapidly being adopted.

Conversely, as the rapid technological development of telepathology has increased the amount of data transfer required, feasibility is increasingly limited to facilities linked via a fiber-optic network. Satellite technology, which can achieve universal coverage far more easily than landlines, is necessary to expand the use of telepathology worldwide. However, until now satellites have been weather-dependent, and prone to choppy image and video transmission. In Japan, the use of ultra-high-speed internet satellites – achieving speeds equal to fiber-optic landlines – is being promoted in various fields, including medicine.[14,15] The primary advantage of satellite technology is that, unlike landlines, communication is less limited by distance and infrastructure; it is easy to communicate via satellite with mountainous areas, remote islands, and foreign facilities unreachable by fiber-optic landlines. Ultra-high-speed internet satellite technology could alleviate regional disparity in the quality of medical care by making it possible to perform intraoperative diagnosis, consultation, and distance education with high-resolution pathological images and video.

With the support of the Research and Development Bureau of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT); we tested the satellite telepathology capabilities of the Wideband InterNet working engineering test and Demonstration Satellite (WINDS), which is also known by the nickname "KIZUNA."

MATERIALS AND METHODS

Experiments were carried out over a period of 2 years. Year 1's experiments tested the interface between the WINDS and telepathology equipment, including operability and image quality for enabling optimal diagnosis The two campuses (Uchimaru and Yahaba) of Iwate Medical University (IMU), which are separated by 12 km, were connected using the WINDS to transfer real-time video images for telepathology. Results were compared to those obtained over a fiber-optic connection. In the second year, IMU was connected with Tokyo (530 km) and Okinawa (2,000 km). We evaluated the functionality and usability of remote voice conferencing for pathological diagnosis using virtual slides. Image transfer and audio functions were included.

Equipment

WINDS

An ultra-high-speed internet satellite capable of data transfer rates far exceeding existing commercial satellites.

The latter reached upload and download maximum speeds of 2 and 10 Mbps, respectively. In contrast, the WINDS reaches over 155 Mbps, or more than 15 times the speed of current commercial satellites. The WINDS' coverage is also noteworthy, reaching all of Japan and the major cities of Asia with a fixed antenna. This single satellite can communicate with points on nearly one-third of the globe, with minimal geographical limitations with a beam-hopping antenna [Figure 1].

Warp Scope

A real-time remote microscope diagnostic system. The diagnostic facility can remotely adjust focus, zoom, and stage position in real-time. Used for remote intraoperative pathological diagnosis and cytodiagnosis over fiber-optic lines. Video transmission uses WarpVision.

Specifications

Real-time remote microscope diagnostic system developed by Finggal Link Co., Ltd. (Tokyo, Japan). Image size: 1920 × 1080 at 30 fps. Objective lenses: ×1.25, ×2.5, ×5, ×10, ×20, ×40, ×63. Control: X, Y stage movement, Z focus movement. Light adjustment: Condenser.

Warp Vision

A video communication service (or software) developed and trademarked by NTT Communications (Tokyo, Japan). The standard resolution version encodes and transfers 8 Mbps of video data at 640 × 480 (30 fps). The high-definition version encodes and transfers 16 Mbps of video data at 1920 × 1080 (30 fps). Video and audio delay is less than 200 ms in both versions, making conversation and remote operation smooth.

Virtual Slides

Created by digitally scanning glass slides as high-resolution digital images using a digital scanning system for the purpose of medical digital image analysis. When viewed on a computer with image management software, zoom, viewing area, etc., can be adjusted as with a microscope. Maximum optical zoom is limited by image resolution.

Virtual Slide-Related Products

ScanScope CS2 eSlide capture device and Spectrum software for digital slide management, and ImageScope viewing software (Aperio Technologies, Vista, CA, USA). Conferencing functions, including screen sharing, field movement, zoom, and annotation were tested.

Evaluated Items

This series of experiments evaluated the communications network, operability of the remote medical equipment, and the feasibility of remote diagnosis with pathological images.

Communications Network

Communication quality and maximum transfer speeds were evaluated on the WINDS experimental network, including earth stations (terrestrial terminal stations used for telecommunication with satellites and/or spacecraft, or to receive radio waves from astronomical sources). Earth stations were established at Iwate Medical University, the International University of Health and Welfare (IUHW) Mita Hospital (Tokyo), and the University of the Ryukyus (Okinawa). Figures 2a and b illustrates the conferencing network setup used in 2nd year of experimentation.

Operability of Remote Medical Equipment

We examined the interface between the WINDS and telepathology equipment (real-time video and virtual slide systems) and the operability of this system as a whole. In year 1, the communication quality of the WINDS was compared with that of land-based fiber-optic networks.

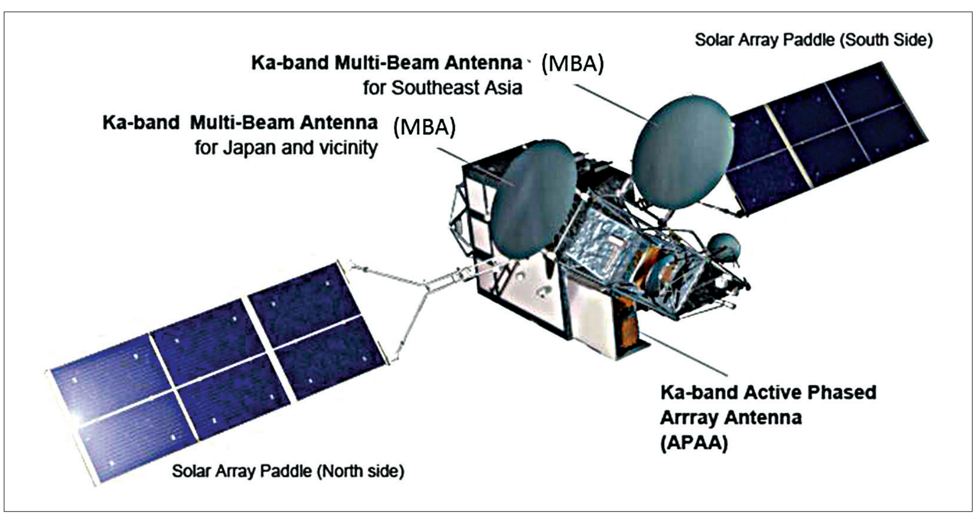

Figure 1: WINDS diagram. WINDS is a geostationary communications satellite with two solar array paddles, multi-beam antennas covering Southeast Asia with 19 fixed-spot beams, and active phased array antennas covering the Asia-Pacific region with two scanning spot beams

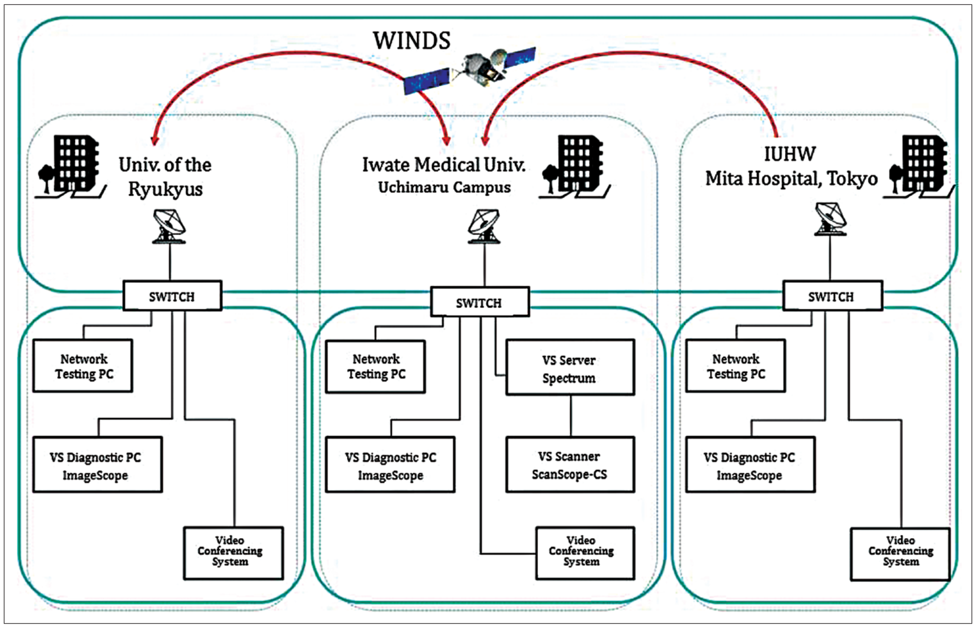

Figure 2a: Network diagram. Earth stations were placed in the three participating institutions in (Iwate Medical University, Iwate; IUHW Mita Hospital, Tokyo; University of the Ryukyus, Okinawa). Additionally, a scanner and server were placed at IMU. IUHW Mita Hospital and the University of the Ryukyus acted as client institutions and IMU as the consulting hospital

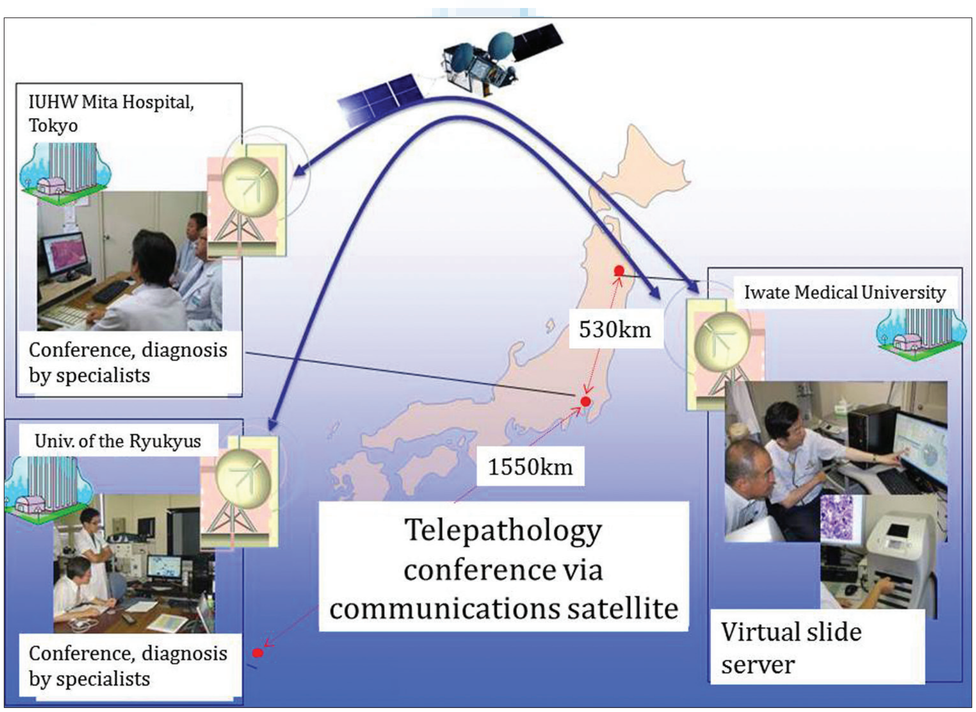

Figure 2b: Conferencing. Using virtual slides stored in the IMU server and a teleconferencing system, we had a pathological conference between Iwate Medical University, Iwate; IUHW Mita Hospital, Tokyo; and the University of the Ryukyus, Okinawa

Remote Image Diagnosis

The cases used in our experiments are illustrated in Tables 1 and 2. In year 1, we examined whether or not *Helicobacter pylori* (*H. pylori*) were identifiable with both standard and high-definition images. In year 2, three-way conferencing was tested between institutions in Iwate, Tokyo, and Okinawa. Each location was given control in turn, and 10 cases with significant treatment implications were examined. These cases included cytodiagnosis, a bone marrow smear, HER2 protein expression in breast cancer, and others of interest in targeted therapy.

Table 1: Year 1 cases

Procedure	Clinical diagnosis	Purpose
Gastric biopsy, H and E stain	Gastritis	Diagnosis and determination of histological characteristics
Gastric biopsy, Giemsa stain	Gastritis	Diagnosis and confirmation of *H. pylori* infection
Gastric biopsy, H and E stain	Gastric polyp	Diagnosis, confirmation of histological characteristics
Colon biopsy, H and E stain	Colitis	Diagnosis, confirmation of histological characteristics
Colon biopsy, H and E stain	Colon cancer	Diagnosis, histological typing
Lung biopsy, H and E stain	Lung cancer	Diagnosis, histological typing for therapeutic implications
Stomach biopsy, H and E stain	Stomach cancer	Diagnosis, histological typing
Rectal biopsy, H and E stain	Rectal cancer	Diagnosis, histological typing
Rectal surgical material, IHC (CEA)	Rectal cancer	CEA expression, and IHC confirmation of positive area

H and E: Hematoxylin and eosin, IHC: immunohistochemistry, CEA: carcinoembryonic antigen. Pulmonary and gastric tissue: Histological differentiation of pulmonary tissue made in relation with treatment. H. pylori: H. pylori positively identified. High-definition telepathological images were used because H. pylori is difficult to identify at standard resolution. Colon cancer immunostaining: Stainability of cancerous and non-cancerous areas of a single specimen was compared using carcinoembryonic antigen (CEA) to discriminate tumor and none tumor

Table 2: Year 2 three-way conferencing

Subject	Context/content	Purpose	Therapeutic implications
Lung surgical material H and E	Frozen section	Quick diagnosis classification of lung cancer	Determination for surgical procedure
Esophagus surgical material H and E	Frozen section	Quick diagnosis tumor residue in surgical margin	Determination for further excision
Thyroid gland surgical biopsy H and E	Parfaffin section	Cancer or not from nuclear properties	Selection of treatment
Bone marrow smear Giemsa	Blood smear	Nucleus/cytoplasmic features associated with leukemia	Selection therapeutic procedure
Lung cytological diagnosis papanicolau	Cytological specimen	Malignant or not cytoplasm and nuclei	Determination for therapy
Breast biopsy H and E	Paraffin section	Difficult case Intraductal or extraductal invasion	Selection for surgical therapy
Mammary gland surgical biopsy H and E	Paraffin section IHC (HER2)	Score of HER2 protein, for therapy	Determination of hormonal therapy
Skin biopsy H and E	Paraffin section IHC (Ki-67)	Number of Ki-67, proliferative marker for malignancy	Selection for therapy high
Lymph node biopsy H and E, IHC	Paraffin section IHC	Monoclonality of lymphocytic tumor	Selection of therapy as plasmacytoma
Lymph node biopsy H and E	Consultation of lymph node granuloma	Classification of granuloma	Selection of therapy against tuberculosis

We examined 10 cases requiring histo- and cytodiagnosis. The specimens tested included tissue from the surgical margin (1, 2), difficult conventional histological diagnosis (3, 6, 10), a bone marrow smear (4), cytological diagnosis (5), and therapeutic uses of IHC (7, 8, 9). Samples included systemic organs; staining and evaluation procedures and treatment options vary by case

RESULTS

Communication Network

Communication Quality

We used standard network testing tools (ping and Iperf) to evaluate communication quality using the WINDS. As shown in Table 3, round-trip time (RTT) averaged 780 ms during year 1 and 800 ms in year 2. These values are in the expected normal range for the WINDS communication network. Iperf measurements of bitrate, loss, and jitter indicated normal communication quality [Table 4].

Maximum Speed

As shown in Table 5, in year 1, Iperf measured maximum data transmission rate (without application equipment attached) at 38.3 Mbps. In year 2, maximum speed was measured at 19.1 Mbps in all legs of the Iwate-Tokyo-Okinawa three-way conferencing.

Comparison with Fiber-Optic Network

As shown in Table 6, the data loss rate for communications on fiber-optic landlines was measured at a stable 0%. The WINDS experienced negligible packet loss, and error correction ensured minimal frame dropping. The WINDS achieved stable video transmission of 16 Mbps at roughly 30 fps. Video and audio packet jitter was significantly greater using the WINDS than the fiber-optic connection, but was found to be within normal values for its application mode.

Table 3: RTT measured with ping

	Sender→Receiver	Minimum	Mean	Maximum
Year 1 2010.1.27				
1 hop	Uchimaru→Yahaba	740.471	781.413	819.152
	Yahaba→Uchimaru	740.807	779.588	818.951
Year 2 2011.6.30				
1 hop	Iwate→Tokyo	746.813	786.608	825.848
	Tokyo→Iwate	756.958	794.970	836.155
	Iwate→Okinawa	746.982	785.855	824.997
	Okinawa→Iwate	775.997	811.766	854.027
2 hop	Tokyo→Okinawa	1576.921	1604.343	1625.646
	Okinawa→Tokyo	1535.765	1572.741	1614.639

ping: A network administration utility to test host reachability and measure RTT. RTT: Round-trip transmission time between the origin and terminal points of a signal, in this case between the satellite and earth stations. Hop: An excursion from one earth station to another via a communications satellite. 1 hop: Earth Station A → satellite → Earth station B. 2 hops: Earth station A → satellite → earth-based relay station → satellite → Earth station B

Table 4: Iperf results

	Client→Server	Bitrate (Mbps)	Time (s)	Loss	Jitter (ms)
Year 1 2010.1.27	Uchimaru→Yahaba	29	60.0	0	0.604
	Yahaba→Uchimaru	29	60.0	0	14.253
Year 2 2011.6.30	Iwate→Tokyo	14	60.2	0	15.621
	Tokyo→Iwate	14	60.3	0	18.354
	Iwate→Okinawa	14	60.0	0	1.210
	Okinawa→Iwate	14	60.2	0	15.959

Iperf: A network testing tool with parameters adjustable to measure packet transmission rates, bandwidth, etc. Loss: Packet loss (%) measured by Iperf. Jitter: Data transmission latency (delay) variation

Table 5: Maximum measured transfer speeds

	Client→Server	Bitrate (Mbps)	Time (s)	Loss
Year 1 2010.1.27	Uchimaru→Yahaba	38.3	60.0	0
	Yahaba→Uchimaru	38.3	60.0	0
Year 2 2011.6.30	Iwate→Tokyo	19.1	61.2	0
Max. transmission rate: 19.5 Mbps	Tokyo→Iwate	19.1	61.2	0
	Iwate→Okinawa	19.1	60.7	0
	Okinawa→Iwate	19.1	61.2	0

The maximum transmission speed of the WINDS communication network system is the nominal 155 Mbps. However, the earth station used in this experiment was limited to 51 Mbps. In this case, the effective rate was about 38 Mbps (about 70% of the nominal rate). Year 1 connected client and diagnostic facilities directly; the effective transmission rate was 38 Mbps. Year 2 connected client and diagnostic facilities through Tokyo, halving the effective transmission rate

Table 6: Comparison of the WINDS with fiber-optic network

	WINDS		Fiber-optic landline	
	Yahaba→Uchimaru	Uchimaru→Yahaba	Tokyo→Okinawa	Okinawa→Tokyo
Transmission rate (kbps)	16043	16021	1675	929
RTT (ms)	821.78		43.16	
Loss (%)	0.334	0.42	0	0
Video packet jitter (ms)	14.87	14.42	1.71	0.95
Audio packet jitter (ms)	14.7	13.65	1.62	0.87
Measurement time (s)	46		428	

The above data was calculated from packets captured by logging tools installed in the client computers at each transmission terminus. In application mode, the WINDS uses WarpVision HD (full high definition = 1920×1080) while the fiber-optic network uses WarpVision (QVGA = 320×240). The transmission rate disparity reflects the resolution differences

Operability of Remote Medical Equipment

WarpVision Real-time Video System (Year 1)

For diagnosis to be made, remote microscopy requires manipulability of the field of vision, zoom, and focus. Overall, the functionality of high-definition image manipulation presented no significant difficulty and was comparable to that with a fiber-optic connection, though the focus lagged approximately 0.8 s.

Virtual Slides (Year 2)

We accessed the Spectrum digital slide management server and confirmed that virtual slides were viewable. The virtual slide images were dithered (displayed as a low-resolution mosaic) while loading, and took approximately 1 min to fully load. Once completely loaded and displayed at full resolution, no inconvenience was experienced in adjusting the field of vision or zoom. Additionally; shape, stainability, and some level of microstructure were observable.

Pathological Image Cases

Year 1 Cases

Gastric Cancer Biopsy

A biopsy containing both undifferentiated carcinoma and normal tissues was compared. Cellular characteristics of the invasive cancer cells with significant atypia were clearly confirmed and diagnosis was possible with no difficulties.

H. pylori Confirmation

Identification of *H. pylori* is difficult with standard-definition images, but not with the high-definition images used in these experiments. *H. pylori* were confirmed with both Giemsa and hematoxylin and eosin (HE) staining, as shown in Figure 3.

Colon Cancer Immunostaining

The cancerous area exhibited brownish-red color indicating positive reaction to the antibody, while the noncancerous area was negative.

Lung Tissue

Cancerous and normal cells were easily distinguishable on the basis of histo- and cytological findings such as cytoplasmic anomalies, nuclear atypia, and chromatin coarseness.

Year 2 Cases

We accessed the digital slide server at IMU from two remote points (IUHW Mita Hospital, Tokyo and University of the Ryukyus, Okinawa) and viewed virtual slides. The results of conferencing conducted via the WINDS are summarized below.

Lung Tissue

Tissue sample excised from a lesion from an abnormal chest X-ray shadow. Consultation requested to diagnose and determine treatment. Diagnosis according to Noguchi's classification type A of adenocarcinoma,[16] required focal rather than extended resection lobectomy or radical lymph dissection (lymph adenectomy). (IMU case.)

Esophageal Tissue

Consultation on pathological diagnosis revealed cancer remaining in the marginal region. Additional resection required. No relapse at the time of writing. [Figure 4; IMU case]

Thyroid Tissue

Consultation on malignancy for postoperative histological specimen. Nuclear grooves and inclusion bodies identified, and diagnosed as papillary adenocarcinoma (follicular variant); total thyroidectomy performed with radical dissection of cervical lymph nodes [Figure 5; University of the Ryukyus case].

Bone Marrow Smear

Diagnosis of smeared slide with suspected hemopathies, including leukemia. Images at ×20 magnification insufficient to identify nuclear and cytological characteristics necessary for diagnosis; ×40 images required instead. Diagnosed as benign. (IMU case.)

Pulmonary Cytodiagnosis

Cellular and nuclear characteristics and cellular alignment and overlap are considered diagnostic indicators of

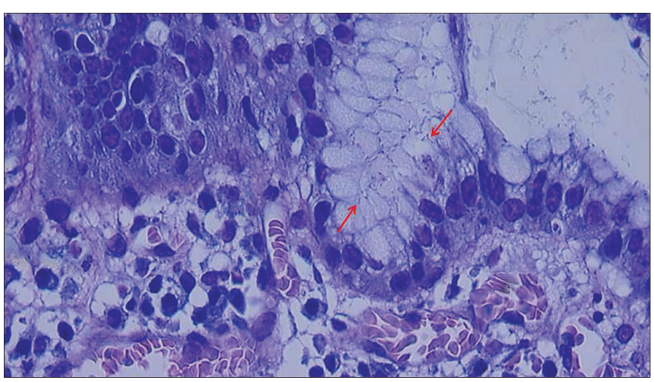

Figure 3: Giemsa staining *Helicobacter pylori* were visible, with club-shaped figures (25.5 μm in length). *H. pylori* is implicated in the genesis of stomach cancer and malignant lymphoma (arrows)

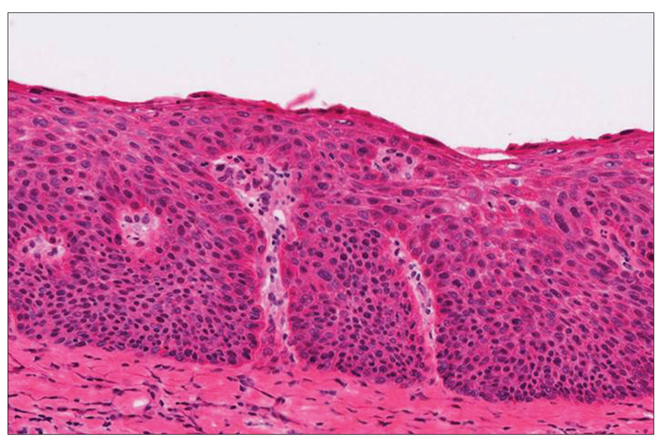

Figure 4: Esophageal tissue specimen. Additional excision was performed for esophageal carcinoma because of atypical cell residue on the surgical margin

malignancy. Cytodiagnosis is methodologically simpler than histodiagnosis. This case diagnosed as pulmonary adenocarcinoma based on nuclear atypia and size variation, increased chromatin levels, and cellular overlap. The ×20 images were diagnostically sufficient. However, cytodiagnosis found to require rapid focus adjustment [Figure 6; IMU case].

Mammary Gland
Difficult case of suspected invasive breast cancer. Primarily intraductal, but slight extraductal invasion confirmed. Only local tumor resection and close follow-up required (IUHW case.)

Mammary Gland
Scoring of immunohistochemical HER2 reactivity for selecting antibody therapy [Figure 7]. Recently, targeted antibody therapy has joined the regimen of resection and chemotherapy. Immunohistochemistry (IHC) is used for scoring the amount of HER2 protein, and selecting appropriate treatment. Three samples were immunostained and scored at each facility. All diagnoses matched; two were categorized as score 3, and one as score 2. This sample was referred for fluorescence *in situ* hybridization (FISH). (IUHW case.)

Skin Biopsy
Suspected benign dermatofibroma of the forearm. However, cellular density and nuclear characteristics indicated possible malignancy. Sample immunostained with cellular proliferation marker ki-67. Unable to rule out malignancy despite low ki-67-positive cell count. All three facilities agreed on need for additional immunostaining with CD34 or consultation with dermatopathologist. (IMU case.)

Lymph Node Biopsy
Swelling of lymph node with cell proliferation, characterized by cell shape and nuclear position. Additionally, immunohistochemical staining demonstrated only κ-chain immunoglobulin-positive cell proliferation, led to diagnosis as kappa-type plasmacytoma. Cellular characteristics and positive immunostaining observable and acceptable to all conferencing participants. (University of the Ryukyus case.)

Lymph Node
Swelling of lymph node diagnosed as noncancerous sarcoidosis. Granuloma in this case characterized by little confluence and necrosis. (University of the Ryukyus case.)

DISCUSSION

The WINDS is one of many Japanese satellites. In addition to communications, satellites are used for weather forecast, disaster prevention, and numerous other purposes in Japan.[17] The WINDS was developed by the Japan Aerospace Exploration Agency (JAXA) and the National Institute of Information and Communications

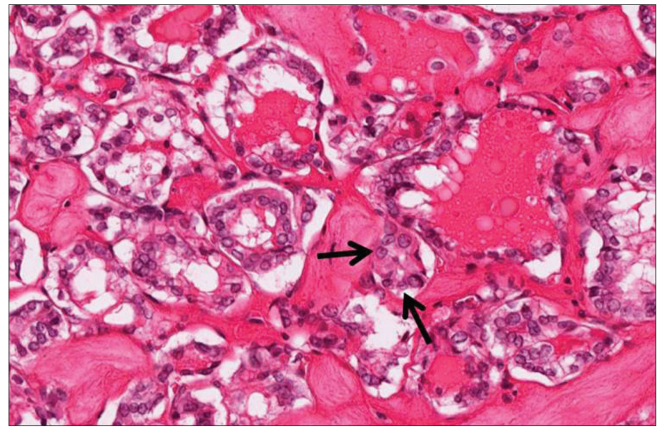

Figure 5: Thyroid tissue specimen. Thyroid tumor: Diagnosis was papillary carcinoma (follicular variant) with nuclear grooves

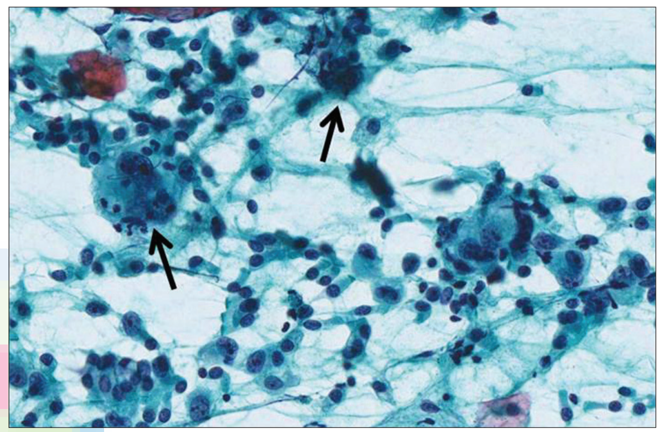

Figure 6: Pulmonary cytodiagnosis. Cytological diagnosis for sputum: Adenocarcinoma with cluster formation composed of many atypical cells

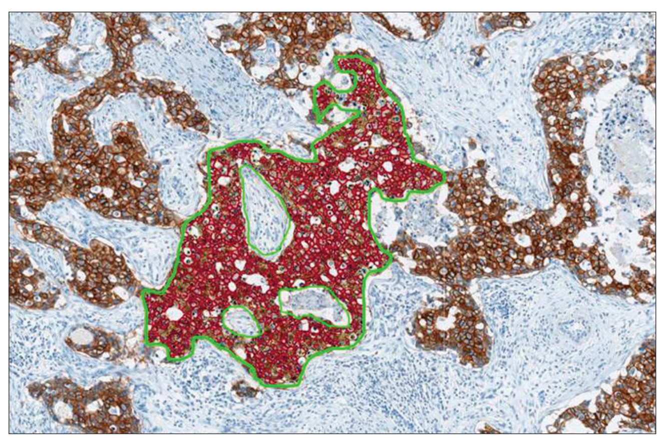

Figure 7: Mammary gland specimen. The patient received antibody therapy based on the result of immunohistochemical score 2 reactivity for HER2 protein

Technology (NICT) in order to overcome the digital divide and provide universal broadband internet service. The satellite is nicknamed “Kizuna” (“connection,” or “human bond” in Japanese), a word which has special resonance after the earthquake and tsunami of March

11, 2011. The WINDS is still experimental, but potential uses include industrial, scientific and educational services, as well as to provide information for use in disaster prevention. The WINDS is distinguished by a combination of mobility, wide coverage area, and robustness in the event of disaster. It provides higher data transfer speeds using smaller antennas than existing communications satellites. Portable user terminals receive 155 Mbps with 45 cm aperture antennas and transmit 155 Mbps with 1.2 m antennas. Terminals of this size are easily transportable anywhere within the satellite's coverage area. The WINDS has fixed antennas for Japanese and major southeastern Asian cities, and high-speed scanning antennas that provide total coverage of nearly one-third of the globe without reliance on landline infrastructure. This means that if a natural disaster interrupts land-based networks, portable the WINDS terminals can easily be transported into affected areas and easily set up alternative network service. For instance, after the disaster of March 11, 2011, the WINDS mobile earth stations were installed at the Iwate Prefectural Office and the affected coastal cities of Kamaishi and Ofunato, allowing high-definition videoconferencing and internet access.[18] These characteristics mean that, unlike fiber-optic cable networks, the WINDS can provide service in mountainous regions and isolated islands. The WINDS uses an ethernet connection, making it highly compatible with land-based internet networks. The WINDS and landlines can be used complementarily to create more reliable networks. The success of these telepathology experiments indicates that the WINDS interface is well adapted for remote medical services. In the future, it is expected that the WINDS will be used to provide telemedicine services and medical cooperation for the Asia-Pacific region.

Japan has numerous public and private communications satellites in use [Table 7], but the WINDS is capable of data transmission speeds far outstripping any of them. Because telepathology requires the transfer of very large amounts of data, it is highly unlikely that any other available satellite could achieve the image quality and stability necessary for telepathology.

Virtual slides require more preparation (scanning) time than real-time video, but once prepared and saved to a server, they are accessible from anywhere.[19,20] Virtual slides are used around the world in educational settings; according to Weinstein, students at Arizona University use virtual slides exclusively, completely discarding optical microscopy.[1] The Japanese Ministry of Health, Labor, and Welfare (MHLW) has helped fund the purchase of about 250 scanners nationwide for the "standardization of cancer medical services". Throughout the country, 60% of medical schools have introduced virtual slides, and 20% of facilities with virtual slide capability use them in lectures and practice.[21]

WarpScope is a dynamic robotic telepathology system capable of real-time video function.[13] The diagnostic pathologist can select the visual field freely and control the focus of microscope in a user environment almost identical to a traditional optical microscope. Recently, high-definition equipment has been developed. We used high-definition images in WarpScope via WINDS to identify *H. pylori* (2.5-5 μm) bacteria, which are associated with occurrence of gastritis and gastric cancer.

In the first year of this series of experiments, we performed pathological diagnosis using a robotic microscope with real-time video. In the second year, we confirmed that three-way conferencing using virtual slides was feasible via a WINDS connection. Network parameters measured with ping and Iperf were normal, but stage movement, zoom, and conversation suffered a lag of approximately 0.8 s. A delay averaging 60-90 s was experienced when initially accessing virtual slides saved to the server. When one participant changed the objective field significantly, there was a delay of 10-15 s before the slide image was reloaded at the other two sites. Jitter using the WINDS network ranged from 0.604 to 14.253 ms. During loading, images were mosaicked. This phenomenon was unusual when using a fiber-optic network, and may have been due to weather conditions.

No direct connection was established between Tokyo and Okinawa for three-way conferencing. Therefore, communication between these two points required two hops (sender-satellite-Iwate-satellite-receiver). As a result, RTT was nearly doubled [Table 3] over single hop connections, resulting in image and voice transmission delays. This is characteristic of communications satellites.

Conferencing was highly successful. We were able to manipulate the images as we conversed, and all participants reached consensus on histopathological findings; including nuclear shape, cellular characteristics, and structure; and immunostaining results. Our results indicate that, for both educational and pathological applications, WINDS could serve as an effective substitute when and where fiber-optic networks are not available. There are many possible uses for the WINDS. We expect that in the future, WINDS will also be used to communicate with foreign facilities. In addition to consulting with hospitals in the United States and Europe, it should be possible to assist with diagnosis, training, and quality control in Southeast Asia.[22] A high-speed broadband satellite like WINDS could service areas unreached or unreachable by fiber-optic networks (mountainous and desert regions, and isolated islands) resulting in tremendous medical advancements for mankind.

CONCLUSION

These experiments demonstrate that the WINDS ultra-high-speed internet satellite is suitable both for

Table 7: Japanese communications satellites

Satellite (band)	Service (provider)	Domestic users	Fixed/ transportable	Size	Output	Weight	Transfer speed (bps)	Interface
WINDS (Ka)	Ultra-high-speed internet (JAXA/ NICT)	N/A	Fixed/ Transportable (Loan)	120 cm	40 wSSPA	90 kg	1-155 M	RJ-45 Router and TCP accelerator connection
ETS-VIII (S/Ka)	Engineering test satellite (JAXA/ NICT)	N/A	Fixed/Mobile (Loan)	285×374× 125 mm 28.5×78× 174.5 mm		8.2 kg 300 g	Voice: 5.6 k Data: 32 k Packets: 1024 k Broadcast: 220 k×6 cH	140 MHz band IF I/O RJ-45 Ethernet
Thaicom-4 (Ku/Ka)	IPSTAR internet service (IPSTAR Co., Ltd.)	IPSTAR Co., Ltd.	Fixed c. 150,000 yen (+ installation fee)	120 cm/ 84 cm	1 w	20 kg /10 kg	Home: 1 M/512 k Flex: 2 M/1 M Dual: 2 M/2 M Pro: 3 M/1 M Biz: 4 M/2 M	RJ-45
Inmarsat (L)	BGAN (Inmarsat)	KDDI Softbank JSAT Mobile Japan Digicom	Fixed/ Transportable (Car-/ship-mountable) EX500: c. 400,000yen ea. EX700: c. 700,000yen ea.	Explorer500 218×217× 52 mm Explorer700 297×339× 51 mm	14 w 14 w	1.5 kg 3.2 kg	Voice: ISDN: 64 k Packets: 492 k Streaming: 128-256 k	Ethernet, USB, Bluetooth Ethernet, wireless LAN, USB, Bluetooth
N-Star (S)	Widestar II (NTT Docomo)	NTT Docomo	Fixed/ Transportable (Car-/ship-mountable) c. 370,000yen	Flat-panel antenna 197×180× 39 mm	2w	1.3 kg	Streaming: 8 k Data: (Packets: 384 k) (64 k data: 64 k)	RJ-45
JCSAT (Ku-band)	ExBird (SKY Perfect JSAT)	SKY Perfect JSAT SNET	Fixed/ Transportable c. 480-680,000 yen ea. Rental: 160,000yen	75 cm	2 w		Internet service Premier: 8M/ 1.2 M Standard: 4 M/400 k	RJ-45 10/100Base-T (Ethernet)
JCSAT (Ku)	PortaLink (SKY Perfect JSAT)	SKY Perfect JSAT	Mobile c. 10 million yen ea.	Flat-panel antenna 744×649× 860 mm	25 WSSPA	20 kg	3 M/1.5M 6M/1.5M 9M/1.5M (HD-capable)	RJ-45 10/100Base-T
Inmarsat (L)	Isat Phone Pro (Inmarsat)	JSAT Mobile NTT Docomo KDDI Japan Digicom	Mobile phone c. $600 ea.	54×170× 39 mm		279 g	Voice: Voicemail: SMS: Data: 2.4 k	Bluetooth 2.0 Micro SD Audio socket Antenna port
Iridium (L)	Iridium 9555 (Iridium)	KDDI Japan Digicom	Mobile phone c. 250,000 ea.	30×55× 143 mm	0.57 w	266 g	Voice: Data: 2.4 k Packets:	miniUSB
Thuraya-3 (L)	Thuraya	Softbank (Limited area)	Mobile phone (w/GSM) c. $500 ea.	53×128× 26.5 mm		193 g (w/battery)	Voice: IP data: 384 k	Data Cable (UDC) with USB connector

This table indicates that the data transmission rates achieved by the WINDS are very high in comparison to those of Japanese R and D, engineering, and commercial satellites currently in service

pathological diagnosis with real-time video and for viewing and manipulating still-image virtual slides for conferencing and consultation. These results indicate that in the future, Japan's WINDS could be used internationally for microscopic image diagnosis, education, and research.

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REFERENCES

1. Weinstein RS, Graham AR, Richter LC, Barker GP, Krupinski EA, Lopez AM, *et al*. Overview of telepathology, virtual microscopy, and whole slide imaging: Prospects for the future. Hum Pathol 2009;40:1057-69.
2. Scoville SA, Buskirk TD. Traditional and virtual microscopy compared experimentally in a classroom setting. Clin Anat 2007;20:565-70.
3. Harris T, Leaven T, Heidger P, Kreiter C, Duncan J, Dick F. Comparison of a virtual microscope laboratory to a regular microscope laboratory for teaching histology. Anat Rec 2001;265:10-4.
4. Weinstein RS, Bhattacharyya AK, Graham AR, Davis JR. Telepathology: A ten-year progress report. Hum Pathol 1997;28:1-7.
5. Weinstein RS, Descour MR, Liang C, Bhattacharyya AK, Graham AR, Davis JR, *et al*. Telepathology overview: From concept to implementation. Hum Pathol 2001;32:1283-99.
6. Kayser K, Szymas J, Weinstein RS. Telepathology in Europe. In: Kayser K, Szymas J, Weinstein RS, editors. Telepathology: Telecommunication, Electronic Education, and Publication in Path, 1st ed. Heidelburg: Springer Verlag; 1999. p. 113-22.
7. Ferreira R, Moon B, Humphries J, Sussman A, Saltz J, Miller R, *et al*. The virtual microscope. Proc AMIA Annu Fall Symp 1997:449-53.
8. Dunn BE, Almagro UA, Choi H, Recla DL, Weinstein RS. Use of telepathology for routine surgical pathology review in a test bed in the Department of Veterans Affairs. Telemed J 1997;3:1-10.
9. Sawai T. Telepathology in Japan. In: Kumar S, Dunn BE, editors. Telepathology, 1st ed. Heidelburg: Springer Verlag; 2009. p. 105-26.
10. Murakami K. Applications of virtual slides via the internet. In: Sawai T, editor. Telepathology in Japan-Development and Practice, 1st ed. Morioka: Celc Inc; 2007. p. 206-9.
11. Sawai T, Uzuki M, Kamataki A, Tofukuji I. The state of telepathology in Japan. J Pathol Inform 2010;1. pii: 13.
12. Yamazaki T, Sawai T, Noda Y, Fujita N, Miyagawa K. Telepathology in the age of fiber optics. In: Sawai T, editor. Telepathology in Japan-Development and Practice, 1st ed. Morioka: Celc Inc; 2007. p. 77-80.
13. Kumagai K. Finggal link warpscope. In: Sawai T, editor. Telepathology in Japan-Development and Practice, 1st ed. Morioka: Celc Inc; 2007. p. 188-90.
14. Japan Aerospace Exploration Agency. WINDS Basic Experiment. Available from: http://winds-ets8.jaxa.jp/winds/en/experiments/basic/index.html [Last accessed on 2013 Jun 20].
15. Japan Aerospace Exploration Agency. KIZUNA (WINDS): Expanding the utilization of space-based, high-speed Internet. Available from: http://www.jaxa.jp/countdown/f14/overview/application_e.html [Last accessed on 2013 Jun 20].
16. Noguchi M, Morikawa A, Kawasaki M, Matsuno Y, Yamada T, Hirohashi S, *et al*. Small adenocarcinoma of the lung. Histologic characteristics and prognosis. Cancer 1995;75:2844-52.
17. Japan Aerospace Exploration Agency. Wideband InterNetworking engineering test and Demonstration Satellite "KIZUNA" (WINDS). Available from: http://www.jaxa.jp/projects/sat/winds/index_e.html [Last accessed on 2013 Jun 20].
18. Japan Aerospace Exploration Agency. Report on JAXA's Response to the Great East Japan Earthquake (Assistance using earth observation satellites and communication satellites). Available from: http://www.sapc.jaxa.jp/antidisaster/20110311report_e/311report0_e.pdf [Last accessed on 2013 Jun 20].
19. Nakayama I, Matsumura T, Kamataki A, Uzuki M, Saito K, Hobbs J, *et al*. Development of a teledermatopathology consultation system using virtual slides. Diagn Pathol 2012;7:177.
20. Rojo MG, García GB, Mateos CP, García JG, Vicente MC. Critical comparison of 31 commercially available digital slide systems in pathology. Int J Surg Pathol 2006;14:285-305.
21. Sawai T. Application of virtual slide for medical education. Jpn J Clin Exp Med (Igaku no Ayumi) 2010;234:288-91.
22. Nabandith V, Pholsena V, Mounthisone P, Shimoe K, Kato S, Aoki K, *et al*. First trial of cervical cytology in healthy women of urban laos using by self-sampling instrument. Asian Pac J Cancer Prev 2012;13:4665-7.