The role of veterans hospitals in Taiwan's medically underserved areas

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Abstract

Background: Notable healthcare disparities can be observed in medical services in remote, rural areas with those in urban areas, primarily because of specialist shortages, inadequate healthcare, and poor transportation. Globally, remote and rural areas face economic, health, and service challenges resulting in a shift toward telemedicine and adjusted insurance systems in such areas. In Taiwan, similar problems have prompted initiatives to improve healthcare access and medical capacity, particularly in medically underserved areas (MUAs). We evaluated the healthcare distribution and capacity in MUAs, highlighting the crucial role of veterans hospitals.

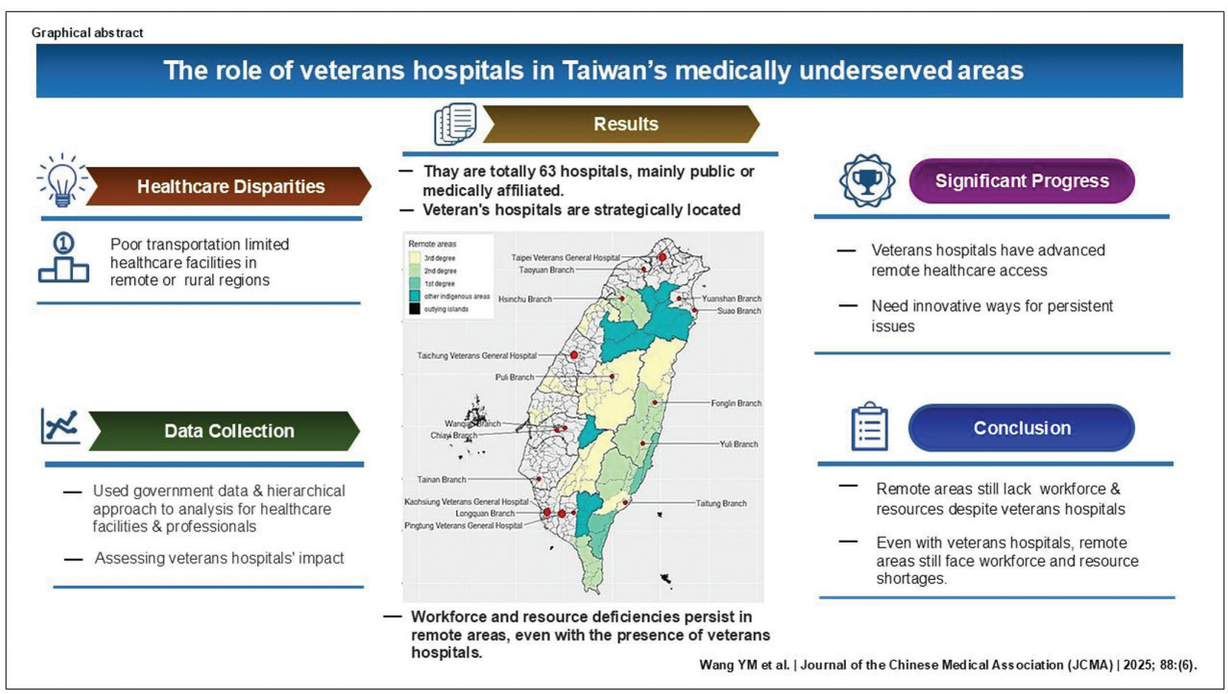
Methods: Using government data and a hierarchical approach, we analyzed the distribution of healthcare facilities and professionals, focusing on the effects of the veterans healthcare system.

Results: Taiwan's MUAs face significant health challenges. While they cover 64.9% of the land, they are home to only 10.9% of the population. These areas rely heavily on clinics, while advanced medical facilities and specialists are sparse, particularly in highly remote regions. Public and affiliated hospitals are essential, but insufficient; they face major shortages in emergency medicine, pediatrics, and surgery. Bed utilization rates are lower in highly remote areas (34.9%) compared with remote areas (81.4% in medical centers). Veterans affairs hospitals play a key role contributing 8.9% of the service capacity. However, workforce and resource deficiencies persist, requiring targeted interventions.

Conclusion: Veterans hospitals play an important role in addressing healthcare disparities in Taiwan's MUAs. By supporting emergency care, community education, and workforce development, these hospitals help to improve medical access in remote regions. Facilities, such as the Hsinchu Branch, exemplify this role by enhancing the local service capacity and medical training. Strengthening rural medical education, expanding telemedicine, and optimizing resource allocation are essential strategies for building a more equitable and sustainable healthcare system.

Keywords: Healthcare disparities; Medically underserved area; Rural health services; Taiwan; Veterans hospitals

Graphical abstract



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Lay Summary: As many as 10.9% of people living in Taiwan's remote and rural areas have difficulty accessing the medical care they need. That is, they live in a medically underserved area, which account for 65% of the land but have a limited number of hospitals and a significantly lower number of medical specialists. Veterans hospitals help fill this gap by offering emergency care and supporting local health programs. However, these areas still lack sufficient medical professionals or staff. This study recommends expanding telemedicine services, increasing the training of rural healthcare professionals, and enhancing the distribution of medical resources to ensure that all individuals in Taiwan can access quality healthcare—no matter where they live.

1. INTRODUCTION

Remote areas differ from urban ones in medical services because of specialist shortages, inadequate healthcare services, and poor transportation, which prevents residents from receiving timely medical treatment.[1] Moscovice and Stensland[2] reported that rural hospitals provide medical services in rural areas, improve rural populations' health status, and bolster individuals' ability to combat environmental threats, thus shaping rural areas' socioeconomy. Approximately 20% of the US population resides in underserved rural areas,[3] which commonly face challenges such as inadequate economic resources, poor health conditions, and limited access to healthcare services.[4] In Australia, recruiting healthcare professionals in rural areas is challenging because of the complexity and diversity of medical services, financial difficulties, and a lack of expertise. Consequently, delivering rural healthcare is extremely difficult. Similar challenges have been encountered in rural areas in other countries, including Canada, the UK, and Europe.[5] To address these challenges, the US rural healthcare policy has gradually shifted toward incorporating Internet medicine. Although implementing telemedicine and optimizing insurance payment systems have considerably improved rural healthcare, medical resource shortages, including low healthcare capacity and multiple financial problems, persist.[6] While the Indonesian government introduced a referral system to address similar challenges, an urban-rural disparity in healthcare resources persists.[7] Rural areas struggle to attract and retain healthcare professionals, and thus, cannot offer the same level of medical services as urban areas. Thus, implementing continual improvement programs, expanding medical services, recruiting and retaining healthcare professionals, and increased medical insurance payments are crucial to enhance rural healthcare quality.[1]

Taiwan also faces insufficient medical resource challenges in its medically underserved areas (MUAs). The Ministry of Health and Welfare (MOHW) has consistently adjusted its policies related to rural areas, such as those regarding the retention system for publicly funded medical students, to improve healthcare accessibility in mountainous areas and outlying islands. The Optimization Plan for Enhancing Rural Healthcare Services was introduced in 2019 to train doctors in remote areas and increase local critical care capacity. This plan categorizes the subregions by three degrees of remoteness. To optimize resource utilization, medical capacity is prioritized for highly remote and remote areas under the MOHW and Veterans Affairs Council's auspices.[8]

Taiwan's veterans healthcare system comprises four veterans general hospitals, 12 veterans hospitals, and 18 veterans nursing homes. They offer emergency, critical, chronic, and long-term care, thereby constituting a comprehensive healthcare system.[9] These institutions are distributed across the country. Except for the recently established Pingtung Veterans General Hospital, all Taiwanese veterans hospitals have a longstanding history. Most are located in nonurban areas, while five are located in remote areas (Fig. 1). Given the remote-urban economic disparities, many often rely on the National Health Insurance (NHI) for medical needs, with few making self-payments for medical treatment at veterans hospitals. Thus, hospital revenues are primarily derived from NHI revenues. To clarify veterans hospitals' role in remote healthcare, we evaluated the capacity and distribution of healthcare services in Taiwan's MUAs by analyzing data from the NHI benefit system.

2. METHODS

2.1. Background

The first Taiwanese veterans hospital was the Taipei Veterans General Hospital, established in 1955. Subsequently, veterans hospitals were established in Zhudong, Puli, Chiayi, Yongkang, Longquan, Nanzi, Fonglin, Suao, Yuanshan, and Yuli during 1957 to 1958. Wanqiao Veterans Hospital was established in 1966. Taipei Veterans General Hospital's Taichung and Kaohsiung branches were established in 1980 and 1990, respectively. They were respectively renamed Taichung Veterans General Hospital in 1988 and Kaohsiung Veterans General Hospital in 1993. In 1994, Nanzi Veterans Hospital was renamed Taoyuan Veterans Hospital. Fonglin Veterans Hospital's Taitung branch was established in 1994 and renamed Taitung Veterans Hospital in 1997. Subsequently, 12 veterans hospitals were vertically integrated as the branches of Taipei, Taichung, and Kaohsiung Veterans General Hospitals.[9] In November 2022, Pingtung Veterans General Hospital was established. The Pingtung branch was renamed Pingtung Veterans Longquan Branch. Thereafter, the veterans' healthcare system has been organized into four medical centers, two regional hospitals, and 12 district hospitals. Together, they offer comprehensive healthcare services to veterans and the general public.

2.2. Data source

To comprehensively evaluate the healthcare resources, we analyzed open government data, including data on the 2019 Optimization Plan for Enhancing Rural Healthcare Services (MOHW),[8] land area and population density of counties and townships,[10] and monthly medical service statistics for hospitals offering outpatient and inpatient services in 2021 (NHI Administration).[11] Additionally, we used a list of NHI-contracted healthcare providers (medical centers,[12] regional hospitals,[13] district hospitals,[14] and clinics[15]), healthcare institutions' profiles, and information on the numbers of medical professionals,[16] doctors practicing in each department in each township and city area,[17] insured beds in 2016,[18] and average utilization rate of beds in each hospital.[19]

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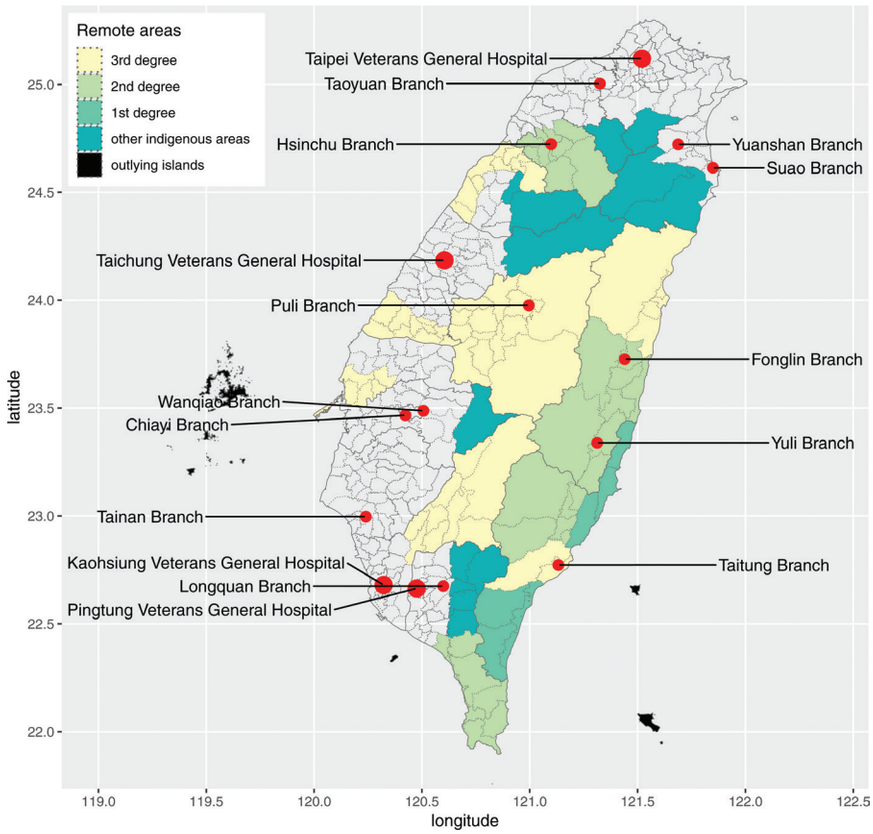

Fig. 1 Spatial distribution of hospitals under Taiwan's veterans medical system.

2.3. Study design

2.3.1. Identify remote areas

Remote areas and subregions were identified based on the subregion remoteness classification system outlined in the 2019 Optimization Plan for Enhancing Rural Healthcare Services to compile a list of remote subregions.

2.3.2. Analyze land area and population density

We analyzed data on the land area and population density of each county and township, and calculated each listed subregion's total land area and population.

2.3.3. Develop a medical institution list

We compared NHI-contracted medical institutions using their hospital code, name, ownership, contract type, and address fields. We then checked the address fields against the identified subregions to compile a list of healthcare facilities located within the MUAs. Finally, each healthcare facility's classification, number of beds, and utilization rate were analyzed.

2.3.4. Measure healthcare service capacity

We measured hospitals' service capacity using the monthly medical service statistics of hospitals offering outpatient and inpatient services in 2021. Subsequently, the capacities of the listed medical institutions in remote areas were compared.

2.3.5. Analyze medical professionals' distribution

We compared healthcare organizations and professionals' profiles to retrieve information on physicians, nurses, and other healthcare professionals in remote areas, and further analyzed the distribution of specialists within the MUAs.

2.3.6. Data analysis and tool application

We analyzed the data on the number of health insurance payment points, physicians, nurses, and other healthcare professionals using Excel (version 2019; Microsoft Corporation, Redmond, WA).

2.4. Ethical considerations

We used publicly available government statistics and did not examine human subjects. Using legally publicized information when the purpose aligns with its publicly known intent is exempt from ethics committee review. This is because the MOHW declares such use under the scope of human research exempt from ethical review. Although only publicly available data were used, all datasets were handled according to data protection principles to ensure privacy and confidentiality.

3. RESULTS

Taiwan's remote and highly remote areas, including 11 third-degree remote subregions, indigenous areas, eight first- and second-degree remote subregions, and six outlying island districts, account for 64.9% of the total land area but only 10.9% of

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the population with an average population density of 109 individuals/km2 (Table 1). Clinics are the most numerous healthcare facilities, with 664 in remote and 173 in highly remote areas, highlighting their critical role in primary care. Health centers are fewer, with 48 in remote areas and 46 in highly remote areas. Advanced medical facilities are scarce, with only 34 district hospitals, eight regional hospitals, and one medical center in remote areas, and even fewer in highly remote areas (Fig. 2).

These regions hosted 63 hospitals, including 43 (68.3%) in remote and 20 (31.7%) in highly remote areas; 19 (30.2%) are public hospitals, 22 (34.9%) are foundation- and

Table 1

Population size, land area, and population density of each medically underserved subregion

Medical care subregion	Degree of remoteness	Population facilities (n)	Land area (km^2)	Population density facilities (n)
Zhudong Subregion	2nd	198 906	1204	165
Coast-Line Subregion	3rd	117 949	293	392
Zhonggang Subregion	3rd	219 934	357	944
Nantou Subregion	3rd	149 182	301	495
Caotun Subregion	3rd	114 480	280	409
Puli Subregion	3rd	109 079	1557	70
Zhushan Subregion	3rd	112 156	1968	57
Beigang Subregion	3rd	134 218	344	391
Southern Changhua Subregion	3rd	284 374	516	551
Qishan Subregion	3rd	125 302	2108	59
Hengchun Subregion	2nd	50 472	511	99
Fangliao Subregion	2nd	38 214	536	71
Hualien Subregion	3rd	238 235	1984	120
Fonglin Subregion	2nd	33 343	1059	31
Yuli Subregion	2nd	49 780	1586	31
Taitung Subregion	3rd	120 776	522	231
Guanshan Subregion	2nd	31 474	1567	20
Dawu Subregion	1st	23 554	853	28
Chenggong Subregion	1st	28 227	509	55
Lienchiang County	Outlying islands	13 645	29	474
Ludao Township	Outlying islands	4124	15	273
Lanyu Township	Outlying islands	5231	48	108
Liuqiu Township	Outlying islands	12 104	7	1,780
Kinmen County	Outlying islands	141 539	152	933
Penghu County	Outlying islands	106 340	127	838
Indigenous areas	Indigenous areas	87 676	5070	17
Total		2 550 314	23 503	109

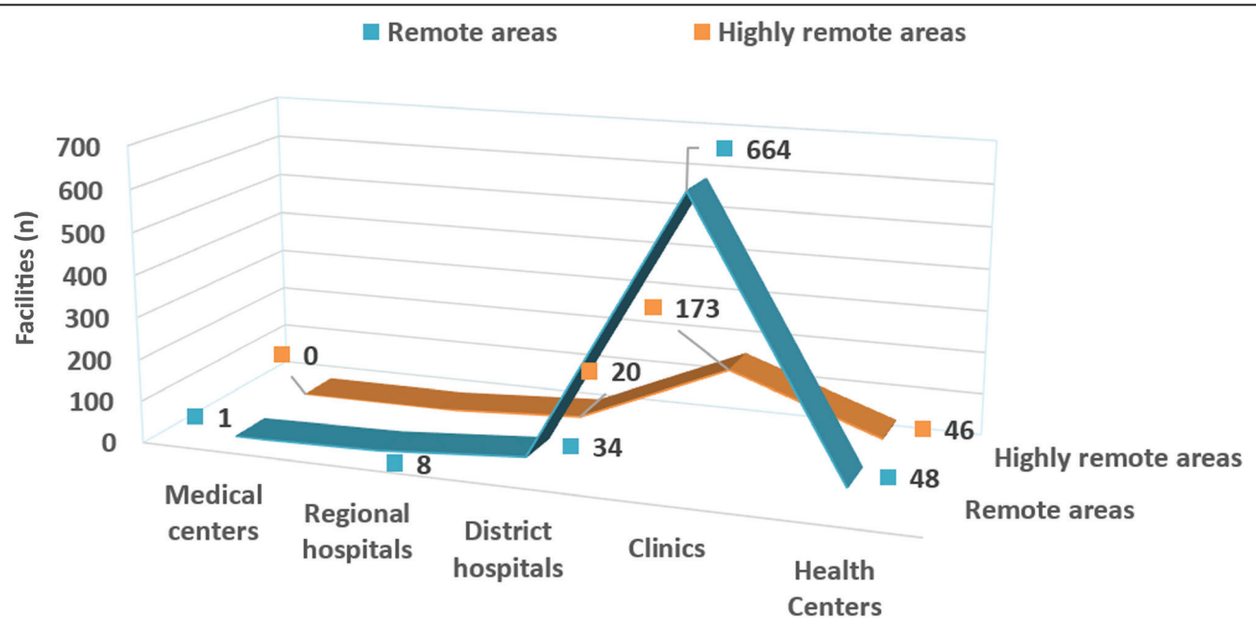

Fig. 2 Distribution of healthcare facilities in remote and highly remote areas of Taiwan medically underserved areas.

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corporation-affiliated, 21 (33.3%) are private Western medicine hospitals, and one (1.6%) is a private medical college hospital (Table 2). Medical foundation-affiliated hospitals have the highest proportion of healthcare professionals (55.9%), followed by public hospitals (33.6%). Physicians and nurses exhibit a similar distribution, although highly remote areas face significant shortages in emergency medicine, pediatrics, and surgery. Internal medicine shows the largest disparity, while specialties like neurosurgery and anesthesiology are universally underrepresented (Fig. 3).

Bed utilization rates are significantly lower in highly remote (34.9%) than in remote areas. Medical centers, regional hospitals, and district hospitals have utilization rates of 81.4%, 52.9%, and 29.5%, respectively. Thus, inpatient services have limited accessibility in highly remote regions.

Veterans Affairs Council hospitals play a critical role in MUAs; the five branches provide 8.9% of the total medical service capacity. The Yuli branch has the highest service capacity and physicians; the Hsinchu branch leads in nursing staff (Table 3). The Hsinchu branch accounts for over 75% of the Zhudong subregion's physicians and nurses. The Puli and Yuli subregions demonstrate a similar concentration (Table 4).

Clearly, significant disparities exist in resource allocation and service accessibility between remote and highly remote areas. Specialist physician shortages and inadequate healthcare infrastructure emphasize the need for targeted interventions to address these challenges.

4. DISCUSSION

4.1. Geographical challenges and medical accessibility in MUAs

Taiwan's medical geography can be divided into six primary regions, 17 secondary medical regions, and 50 subregions; 19 subregions are classified as remote areas. Including outlying islands

Table 2

Types of hospitals in medically underserved areas

Types	Hospitals, N (%)	Bed utilization rates (%)	Payment points, N (%)	Medical professionals, N (%)	Doctors, N (%)
Public hospitals					
Ministry of Health and Welfare Hospitals	11 (17.5)	44.1	5 522 344 498 (15.5)	2572 (19.3)	339 (18.4)
Veterans General Hospitals	5 (7.9)	68.7	3 184 322 216 (8.9)	1332 (10.0)	166 (9.0)
Civilian Clinics of Military Hospitals	2 (3.2)	0.0	1 754 223 206 (4.9)	519 (3.9)	67 (3.6)
County and City Hospitals	1 (1.6)	12.0	78 070 898 (0.2)	58 (0.4)	14 (0.8)
Nonpublic hospitals					
Hospitals Affiliated with Medical Care Foundation	14 (22.2)	43.5	15 478 427 290 (43.5)	6145 (46.1)	938 (51.0)
Hospitals Affiliated with Medical Care Corporation	8 (12.7)	19.2	5 243 130 460 (14.7)	1300 (9.8)	153 (8.3)
Private Western Medicine Hospitals	21 (33.3)	21.5	3 039 935 299 (8.5)	843 (6.3)	104 (5.7)
Private Medical College Hospitals	1 (1.6)	54.2	1 309 260 936 (3.7)	558 (4.2)	58 (3.2)

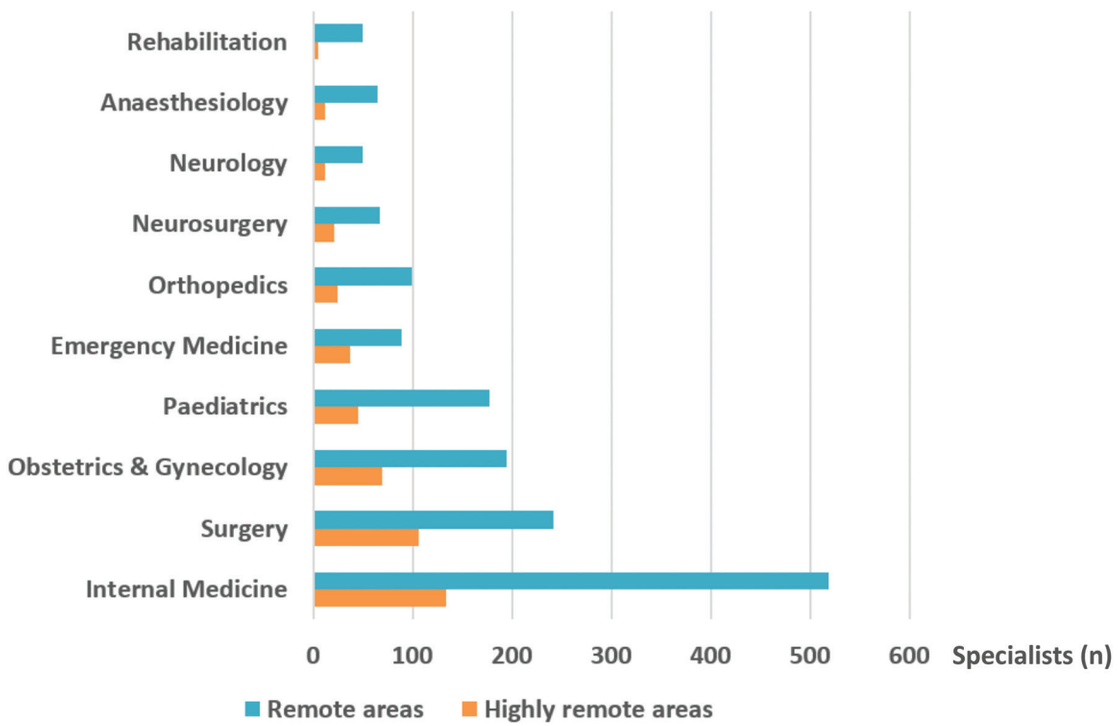

Fig. 3 Distribution of specialist doctors in remote and highly remote areas of Taiwan's medically underserved regions.

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Table 3

Veterans hospitals in medically underserved areas

Hospital	Payment points, N (%)	Medical professionals, N (%)	Doctors, N (%)	Nurses, N (%)	Other medical professionals, N (%)
Taipei Veterans General Hospital					
Yuli Branch	1 000 682 655 (31.4)	375 (28.2)	46 (27.7)	237 (28.2)	92 (28.1)
Hsinchu Branch	846 896 858 (26.6)	378 (28.4)	41 (24.7)	250 (29.8)	87 (26.6)
Taitung Branch	373 658 495 (11.7)	150 (11.3)	24 (14.5)	79 (9.4)	47 (14.4)
Fonglin Branch	202 164 238 (6.3)	94 (7.1)	17 (10.2)	52 (6.2)	25 (7.6)
Taichung Veterans General Hospital					
Puli Branch	760 919 970 (23.9)	335 (25.2)	38 (22.9)	221 (26.3)	76 (23.2)
Total	3 184 322 216 (100)	1332 (100)	166 (100)	839 (100)	327 (100)

Table 4

Veterans hospitals compared with other hospitals in their respective medically underserved areas

Hospital	Payment points, N (%)	Beds, N (%)	Medical professionals, N (%)	Doctors, N (%)	Nurses, N (%)	Other professionals, N (%)
Zhudong Subregion						
Taipei Veterans General Hospital Hsinchu Branch	846 896 858 (80.3)	231 (69.0)	378 (77.9)	41 (75.9)	250 (80.4)	87 (72.5)
Pei-Ling Medical Corporation Aggregate Guan-Si Hospital	126 808 480 (12.0)	60 (17.9)	57 (11.8)	6 (11.1)	35 (11.3)	16 (13.3)
Chushin Hospital	51 471 849 (4.9)	24 (7.2)	21 (4.3)	3 (5.6)	12 (3.9)	6 (5.0)
Lin Hospital	29 603 726 (2.8)	20 (6.0)	29 (6.0)	4 (7.4)	14 (4.5)	11 (9.2)
Subtotal	1 054 780 913 (100)	335 (100)	485 (100)	54 (100)	311 (100)	120 (100)
Puli Subregion						
Taichung Veterans General Hospital Puli Branch	760 919 970 (47.6)	224 (42.4)	335 (42.7)	38 (36.2)	221 (45.3)	76 (39.8)
Puli Christian Hospital	837 512 120 (52.4)	304 (57.6)	449 (57.3)	67 (63.8)	267 (54.7)	115 (60.2)
Subtotal	1 598 432 090 (100)	528 (100)	784 (100)	105 (100)	488 (100)	191 (100)
Yuli Subregion						
Taipei Veterans General Hospital Yuli Branch	1 000 682 655 (54.5)	205 (58.4)	375 (59.8)	46 (57.5)	237 (61.6)	92 (56.8)
Yuli Hospital of the Ministry of Health and Welfare	429 066 588 (23.3)	116 (33.0)	170 (27.1)	23 (28.8)	104 (17.0)	43 (26.5)
Yuli Tzu Chi Hospital	407 903 195 (22.2)	30 (8.5)	82 (13.1)	11 (13.8)	44 (21.4)	27 (16.7)
Subtotal	1 837 652 438 (100)	351 (100)	627 (100)	80 (100)	385 (100)	162 (100)
Fonglin Subregion						
Taipei Veterans General Hospital Fonglin Branch	202 164 238 (85.0)	112 (84.8)	94 (83.2)	17 (89.5)	52 (82.5)	25 (80.6)
Hualien Hospital Fengbin Branch of the Ministry of Health and Welfare	35 549 323 (15.0)	20 (15.2)	19 (16.8)	2 (10.5)	11 (17.5)	6 (19.4)
Subtotal	237 713 561 (100)	132 (100)	113 (100)	19 (100)	63 (100)	31 (100)
Taitung Subregion						
Taipei Veterans General Hospital Taitung Branch	373 658 495 (10.5)	102 (12.3)	150 (10.2)	24 (12.8)	79 (8.2)	47 (14.7)
Taitung MacKay Memorial Hospital	2 361 892 436 (66.5)	435 (52.6)	806 (54.6)	90 (47.9)	582 (60.1)	134 (42.0)
Taitung Christian Hospital	548 376 270 (15.4)	144 (17.4)	313 (21.2)	50 (26.6)	189 (19.5)	74 (23.2)
Taitung Hospital of the Ministry of Health and Welfare	206 962 205 (5.8)	118 (14.3)	155 (10.5)	17 (9.0)	91 (9.4)	47 (14.7)
Taitung St. Mary's Hospital	58 532 020 (1.6)	28 (3.4)	51 (3.5)	7 (3.7)	27 (2.8)	17 (5.3)
Subtotal	3 549 421 426 (100)	827 (100)	1475 (100)	188 (100)	968 (100)	319 (100)

and indigenous regions, remote areas account for nearly two-thirds of Taiwan's land area, yet comprise only approximately one-tenth of the total population with an average population density of 109 people/km2. Certain regions, like Puli, Fonglin, Yuli, and Dawu, have fewer than 100 people/km2. These areas are primarily mountainous or located in eastern Taiwan with limited transportation infrastructure, making them distant from urban hospitals, which results in low healthcare accessibility. Distance is a key medical access barrier in remote rural areas, particularly when individuals have health problems, physical dysfunction, or limited economic resources.[20] Poor transportation infrastructure forces residents to travel for hours to receive medical care. For example, patients from offshore islands may spend more than 3 to 5 hours traveling to a medical center for referral. Residents from mountainous areas face additional challenges due to winding roads and adverse weather conditions, making access impossible during winter or typhoon seasons, thereby further exacerbating emergency healthcare difficulties. High transportation costs and long travel times cause some patients to delay or forgo medical treatment, worsening disease progression, increasing complications, and deepening healthcare disparities. Healthcare facility shortages in highly remote areas are severe because they lack medical centers and regional hospitals, and thus have extremely limited advanced medical resources. Primary healthcare facilities are also scarce, with 3.8 times more clinics in remote than in highly remote areas. The latter also have fewer district hospitals, leaving residents with fewer hospitalization options and further hindering medical service access.

4.2. Healthcare capacity and institutional roles

Clinics are the most numerous healthcare facilities and serve as the main primary care providers. However, most are operated by a single physician or small group of physicians. Services are

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typically limited to a single specialty, causing a relatively constrained healthcare capacity. Public health centers play a crucial role in MUAs, providing primary care while assuming public health responsibilities. This is especially important in highly remote areas, where, despite their limited numbers their functions and importance are particularly prominent. Clinics and health centers in highly remote areas face challenges in patient referrals due to specialist and diagnostic equipment shortages, often requiring transfers to higher-level hospitals. However, geographical barriers, poor transportation, and incomplete healthcare networks hinder referrals. For example, limited ambulance services in mountainous regions can cause emergency transfer delays. Additionally, referral systems and processes affect access to specialized medical care. Taiwan's NHI system adopts a three-tiered referral model that guides patients from primary clinics to regional and tertiary hospitals. However, referral execution in MUAs is impeded by practical constraints such as limited clinic service hours, insufficient specialist availability, and an underdeveloped digital infrastructure for inter-institutional communication. Some hospitals cannot accept referrals due to full occupancy or limited appropriate specialties, further delaying care. Geographical distances and adverse weather conditions delay emergency transportation, especially in mountainous regions. Collectively, these barriers reduce referral efficiency and delay timely access to appropriate care. Clearly, efforts should strengthen telemedicine support, optimize referral procedures, and enhance collaboration between primary and higher-level hospitals.

Outpatient services in MUAs have limited healthcare resources, with fewer advanced medical facilities capable of providing emergency and inpatient services. In highly remote areas, approximately 20 district hospitals can offer such services. Most hospitals in remote areas are public, medical foundation-affiliated, or private Western medicine hospitals. Public hospitals' healthcare capacity is primarily concentrated in MOHW and veterans hospitals. Meanwhile, foundation-affiliated hospitals are mostly church hospitals. Thus, public hospitals and religious organizations play critical roles in rural healthcare.

The only medical center in MUAs has an 81.4% bed utilization rate, while regional hospitals' average is only approximately half. While district hospitals operate at below 30%, they account for half of the total healthcare payment points in MUAs. Thus, they are the main emergency and inpatient medical care providers in remote, particularly highly remote, areas. Their low bed utilization rate may be attributed to the incompleteness of medical specialties, forcing some patients to seek treatment at higher-level hospitals.

Analyzing specialist distribution reveals that in highly remote areas, the numbers of physicians in internal medicine, surgery, obstetrics and gynecology, pediatrics, and emergency medicine are only one-third to one-fourth of that in remote areas, impacting both primary and emergency medical care. Specialists in the trauma and critical care fields, such as orthopedics, neurology, neurosurgery, and anesthesiology, are even scarcer, further complicating trauma and surgical treatment.

4.3. Economic constraints and workforce distribution

Typically, MUAs exhibit lower economic development levels than urban areas, and most hospitals in MUAs rely heavily on health insurance payments, causing relatively low out-of-pocket medical income. This reduces medical revenues and increases difficulties in maintaining operational viability. Although remote areas cover approximately two-thirds of the country, their medical workforce constitutes less than one-tenth, with even fewer physicians.

The public hospital workforce in such areas is primarily distributed within MOHW and veterans hospitals. The low income in MUAs makes it challenging to recruit healthcare professionals, which is common in many countries. Besides providing outpatient and inpatient services, rural hospitals must allocate an additional workforce to implement public health, community health, and health-education initiatives. For instance, fewer individuals are aware of high blood pressure and seek treatment for it in rural areas.[21] This urban-rural gap can be bridged through adequate health education. Thus, community health promotion programs are crucial in MUAs, which cannot be solely measured based on health insurance payment points. Policy support and financial assistance are crucial for maintaining rural healthcare quality.

4.4. Reducing health disparities through policy and community initiatives

Many countries have successfully adopted innovative strategies to improve healthcare services in remote areas. Australia has implemented telemedicine technologies for remote diagnosis and guidance.[22] India uses mobile medical units to provide basic healthcare services.[23] These have significantly enhanced healthcare accessibility and health outcomes. Thus, to reduce urban-rural health disparities in Taiwan, several policy measures should be implemented to address specialist shortages, enhance healthcare accessibility, and optimize resource allocation.

First, telemedicine expansion should continue by integrating it into the NHI system, enabling residents in remote areas to access specialist consultations via digital platforms and reducing long-distance transfers. Further, drawing on Australia's experience, telemedicine reimbursement should be expanded. Artificial intelligence (AI)–assisted diagnostic systems should be developed to improve diagnostic accuracy and strengthen primary healthcare services. For example, Taipei Veterans General Hospital and Taiwan AI Labs developed DeepMets®, an AI tool for detecting brain metastases approved by the TFDA in 2022. It has been integrated into clinical workflows to support diagnostic decisions. The NHI Administration has launched pilot reimbursement programs for such AI tools. AI-assisted diagnostics are gradually expanding beyond tertiary hospitals. The AI Impact Research Center at Taipei Veterans General Hospital has begun implementing clinical AI tools in rural settings, including in the Hsinchu Branch.[24] Concurrently, AI-assisted diabetic retinopathy screening programs using portable fundus cameras have been introduced in rural clinics and health centers. These tools enable non-specialist providers to detect early signs of eye disease and exemplify AI's growing potential to enhance diagnostic capacity and improve healthcare accessibility in Taiwan's MUAs.

Second, the emergency medical transfer system should be reinforced, including establishing an aerial transfer system[25] for offshore islands, and a priority referral system for highly remote areas. MOHW operates an aeromedical transfer system through the National Aeromedical Approval Center primarily for offshore island patients. This includes referral review, coordination with the National Airborne Service Corps, and remote consultation via an online platform.[26] Inspired by India's mobile medical model, a three-tier healthcare system integrating district hospitals, health centers, and mobile medical units should be developed. Additionally, a vertical referral system linking regional hospitals and medical centers should be established to improve healthcare accessibility and referral efficiency in highly remote areas.

Finally, a regional medical resource-sharing model should be promoted by integrating district hospitals, clinics, and health centers to optimize human resource support and equipment allocation. The medical center support program should complement this, along with strengthening circuit medical services

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and home medical care, to establish a comprehensive healthcare support network. These can help improve healthcare quality in MUAs, narrow health disparities, and ensure efficient and sustainable resource distribution.

Merwin et al reported that the proportion of injury-related deaths is 40% higher in remote areas than in urban areas due to rural residents' limited knowledge of preventive medicine and chronic disease control (eg, hypertension and diabetes).[27] According to an Australian study, administering appropriate personalized preventive interventions, and ensuring early disease management through primary and community healthcare can prevent hospitalizations.[28] Therefore, community health education programs should be introduced to facilitate disease management and gradually address urban-rural health disparities.[28,29]

4.5. Innovations in rural medical education and workforce retention

Medical workforce shortage is particularly prominent, similar to the US.[3] Due to the low population density in remote areas, hospitals face financial constraints. This increases the difficulty of offering competitive salaries. Consequently, recruiting and retaining healthcare professionals are crucial for ensuring healthcare services quality in rural hospitals.[30] The World Health Organization's 2010 recommendation of "increasing access to health workers in remote and rural areas through improved retention" indicates that the healthcare professional shortage is the greatest barrier to medical care in MUAs.[31] Efforts should strengthen the publicly funded physician retention program, provide specialist training subsidies, and collaborate with medical centers to create advanced training and academic development opportunities, thereby increasing incentives for young physicians to practice in MUAs. To promote medical personnel localization, rural medical education training centers should be established in MUAs. Community and rural medical education programs can be implemented by fostering partnerships between medical schools and rural hospitals, allowing medical students to intern at primary healthcare institutions in MUAs. This can enhance their sense of identification and adaptability to the medical environment, ensuring the stable development of the medical workforce.

4.6. Veterans hospitals' role

According to Rezaee et al,[32] hospitals should be strategically located to ensure accessibility and rapid response during accidents and disasters. The Veterans General Hospitals are important for improving healthcare accessibility and reducing disparities in Taiwan's MUAs by providing emergency care, community services, and workforce development. Consider the Taipei Veterans General Hospital's Hsinchu Branch, located in the highly remote Zhudong subregion, covering six townships and three indigenous townships. These indigenous townships have uneven population distribution and poor transportation, reducing healthcare accessibility. However, its proximity to expressways and highways enhances medical accessibility for mountainous patients and serves as a crucial transfer hub for referrals to the Taipei Veterans General Hospital. The subregion has four hospitals. The Hsinchu Branch has the most acute care beds and NHI payment points. It also has a superior medical workforce and serves as the subregion's only designated emergency hospital. Located at the center of the subregion, it provides emergency and critical care, circuit medical services, home healthcare, community healthcare, and long-term care.

Additionally, it collaborates with National Tsing Hua University to establish a rural and community medical education model. It has expanded partnerships with National Taiwan University and National Yang Ming Chiao Tung University, actively investing in rural medical education. In recent years, it has trained many future local medical professionals. Simultaneously, it integrates a publicly funded physician retention program, offering training and research subsidies to enhance healthcare personnel's professional skills and willingness to remain in MUAs. The hospital aims to continuously improve medical care quality in remote regions, striving to become a leading rural medical education center.

To strengthen the rural healthcare system, we propose expanding telemedicine services and integrating them into the NHI system; establishing a comprehensive referral and aeromedical transfer system; enhancing local physicians' training and retention incentives; and promoting integration and resource sharing among primary healthcare institutions. Policies should support veterans hospitals' critical role in MUAs to achieve health equity and sustainable healthcare development.

4.7. Limitations and future research directions

First, we primarily rely on government-provided public data, which may contain biases or fail to capture all relevant information. We exclusively focus on quantitative data, excluding qualitative insights like patient experiences or healthcare provider perspectives, potentially limiting the findings' comprehensiveness. Finally, the timeliness of the data is a concern, as we do not account for new or adjusted healthcare facilities established after 2021, which may impact the accuracy of resource distribution assessments.

Scholars should incorporate qualitative research methods to more comprehensively understand MUAs' resource allocation and healthcare accessibility challenges. As telemedicine continues to evolve and healthcare workforce policies are adjusted, scholars should integrate updated data from 2023 to 2025 to ensure that the findings remain relevant and reflect current healthcare developments.

Finally, the Executive Yuan has approved the "Smart and Resilient Health System Program (2025-2029)," which includes annual releases of health equity indicators and data on healthcare accessibility in MUAs.[33] These can provide timely and systematic insights to inform both national and regional health policies. Meanwhile, our research team plans to conduct a qualitative study involving semistructured interviews with frontline healthcare professionals in MUAs, exploring real-world operational barriers, workforce dynamics, and referral experiences. Collectively, these initiatives can provide updated evidence to support future healthcare delivery research and policy planning in remote regions.

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