AI-assisted Assessment of Ankylosing Spondylitis

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Executive Summary

Ankylosing spondylitis (AS) is a chronic rheumatic disease causing inflammation and ankylosis of the spine, limiting movement and quality of life. Disease assessment includes disease activity, measured by Ankylosing Spondylitis Disease Activity Score (ASDAS), and chronic spinal damage, estimated by modified stoke ankylosing spondylitis spinal score (mSASSS) using radiographic images of cervical spine and lumbar spine. ASDAS predicts future spinal adhesions, making it a crucial treatment target. Taichung Veterans General Hospital (TCVGH) has developed a patented electronic medical record management system which integrates patient reported outcomes assessed by smartphone using the TCVGH-developed app and laboratory tests to automatically calculate ASDAS. We also used deep learning to develop an AI-assisted scoring of mSASSS. This technology enables a convenient and quick mSASSS scoring, enhancing patient tracking and treatment planning.

Define the Clinical Problem and Pre-Implementation Performance

Ankylosing spondylitis (AS) is a common chronic rheumatic disease characterized by chronic inflammation of the vertebral joints which may lead to ankylosis of the spine, restrict the movement of the spine and affect the quality of life. The disease assessment of AS can be clinically challenging because of its heterogeneous disease course. Ankylosing Spondylitis Disease Activity Score (ASDAS) and modified Stoke Ankylosing Spondylitis Spinal Score (mSASSS) are two most commonly used tools assess disease activity and spinal damage in patients with AS. They have been certified by various studies for their accuracy in assessing ankylosing spondylitis. ASDAS reflects acute disease activity while mSASSS measures chronic joint destruction. Past studies have shown that ASDAS scores are positively correlated with future spinal adhesions.

Taiwan Rheumatology Association consensus recommendations for the management of axial spondyloarthritis including ankylosing spondylitis recommended clinical target (T2T) of reaching either inactive disease or at least low disease activity. Achieving ASDAS < 2.1 and preferably <1.3 is recommended. The American college of rheumatology (ACR) and European league against rheumatism (EULAR) also recommended ASDAS < 1.3 as an appropriate treatment target.

Despite its importance, the ASDAS score comprises both laboratory measurements and multiple patient-reported outcomes (PROs). The score is calculated through a complex equation based on the aforementioned components. (ASDAS score= 0.12 x Back Pain + 0.06 x Duration of Morning Stiffness + 0.11 x Patient Global + 0.07 x Peripheral Pain/Swelling + 0.58 x Ln(CRP+1) Therefore, clinical use is impractical due to the time consuming process and could only be used in the clinical trial settings. Furthermore, mSASSS involved interpretation of the radiographic change of 12 spinal columns which is commonly used in clinical trial as an ultimate outcome but rarely used in clinical setting because of its time-consuming property and operator-dependent variability. To overcome this, we developed and implemented the Electronic Medical Record Management System (EMRMS) in 2017 and the AI-assisted calculation of mSASSS in 2023 to facilitate routine assessment of ASDAS and mSASSS at Taichung Veterans General Hospital (TCVGH).

Design and Implementation Model Practices and Governance

ASDAS

As soon as the AS diagnostic code is digitally recorded in the outpatient electronic medical record (EMR), it will trigger a window prompt for physicians to enroll the patient into our cohort. If the case is not recorded at the first visit, registration at any time is allowed during subsequent visits for patients meeting the diagnostic criteria for AS. Upon registration, a comprehensive medical history will be collected for the first time, including the onset time of the disease, past medical history, family history, presence of extra-articular symptoms associated with AS (such as iritis, psoriasis, inflammatory bowel disease), involvement of sacroiliac joints, dactylitis, peripheral arthritis, comorbidities, and an initial assessment of disease activity. Patients will self-assess symptomatology, functionality, and health scores using the Taichung General Veteran Hospital app and the electronic medical record management system on their mobile phones. They may seek assistance from a case manager in utilizing the app for self-assessment. Once learned, patients can self-assess on the day of follow-up visits or on the day of blood tests. The electronic medical record management system was co-developed by the physician and information technology specialists to integrate the results of laboratory data from EMR and PRO from mobile app.

mSASSS

To develop an AI assisted mSASSS interpretation system, two steps were taken. First, supervised deep learning process involved collecting data from 646 ankylosing spondylitis patients who have undergone at least one paired (cervical and lumbar spine lateral) X-ray imaging and have clinical assessment results within the past twenty years, resulting in a total of1,056 datasets (each dataset includes cervical and lumbar spine lateral X-ray images taken within a three-month interval). Initially, two rheumatology experts and one radiologist conducted 8 rounds of consensus meeting to interpret the presence or absence of various imaging features. Then majority votes determined the ground truth of all features for the scoring of mSASSS. Subsequently, a supervised deep learning approach is employed to identify a computational function for analyzing and comparing data features and categories based on labeled imaging features using 80% of data. This approach aims to establish an accurate model for scoring spinal lesions and automatically assign lesion category scores. Secondly, test dataset comprised of another 20% of paired images. The test dataset was utilized to validate the original AI model.

Clinical Transformation enabled through Information and Technology

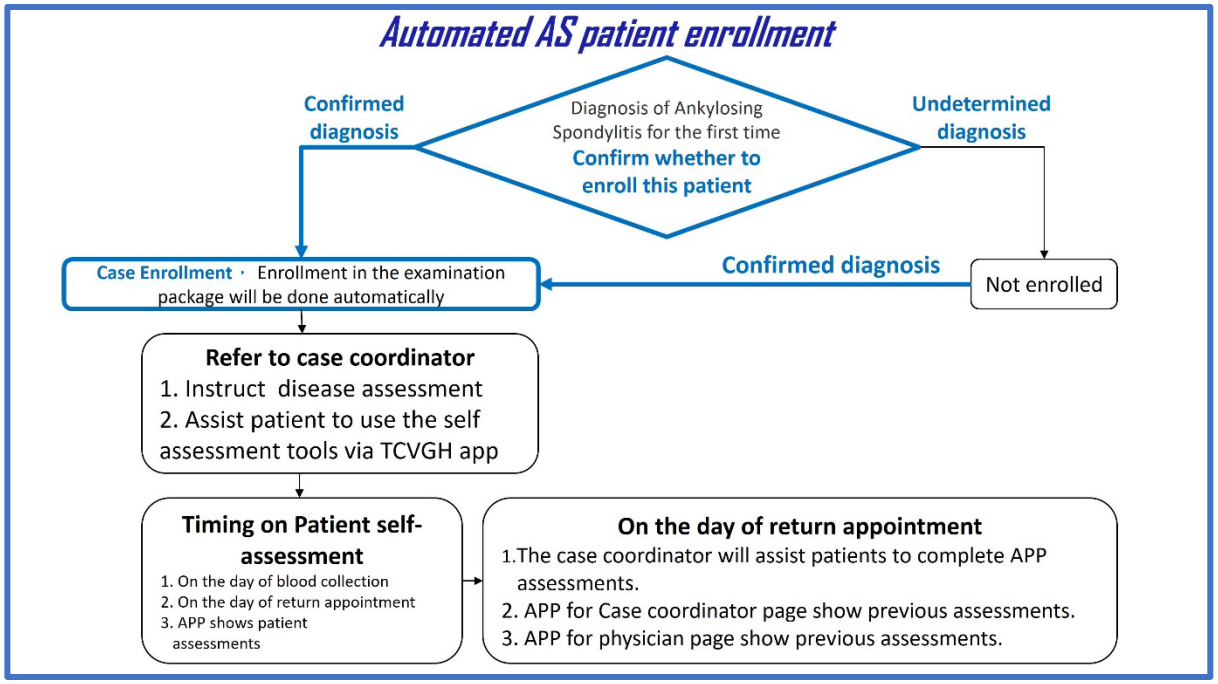

Figure 1. The automated enrollment of patients with ankylosing spondylitis. The automation use improved the enrollment rate.

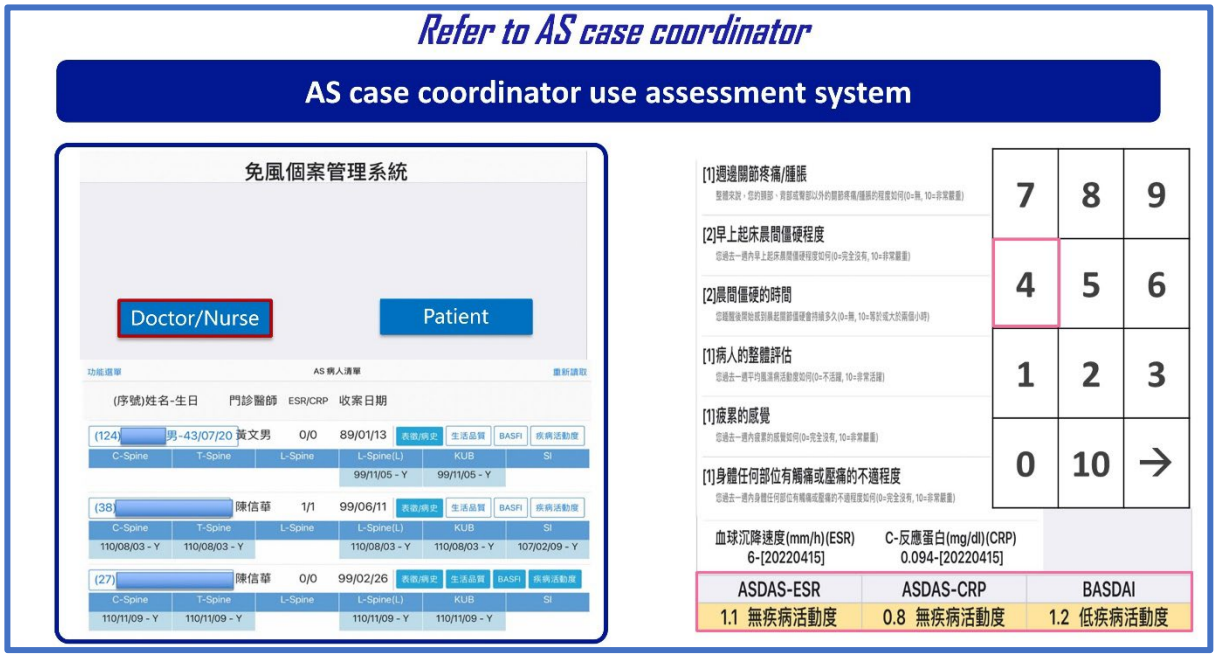

Figure 2. The electronic medical record management system was embedded into the remote device like iPad as well as mobile app. It is available for both the patients and healthcare provider including physicians, nurses and case coordinators to document measurement for disease activity. During the first visit, our case coordinator instructs the patients about procedure on the remote device and mobile app.

Figure 3. The user interface of our mobile app. The patients could easily assess their own patient reported outcomes (PRO) through the app. The PRO is integrated to the laboratory data from our healthcare information system to generate an instant ASDAS score and shown on the app.

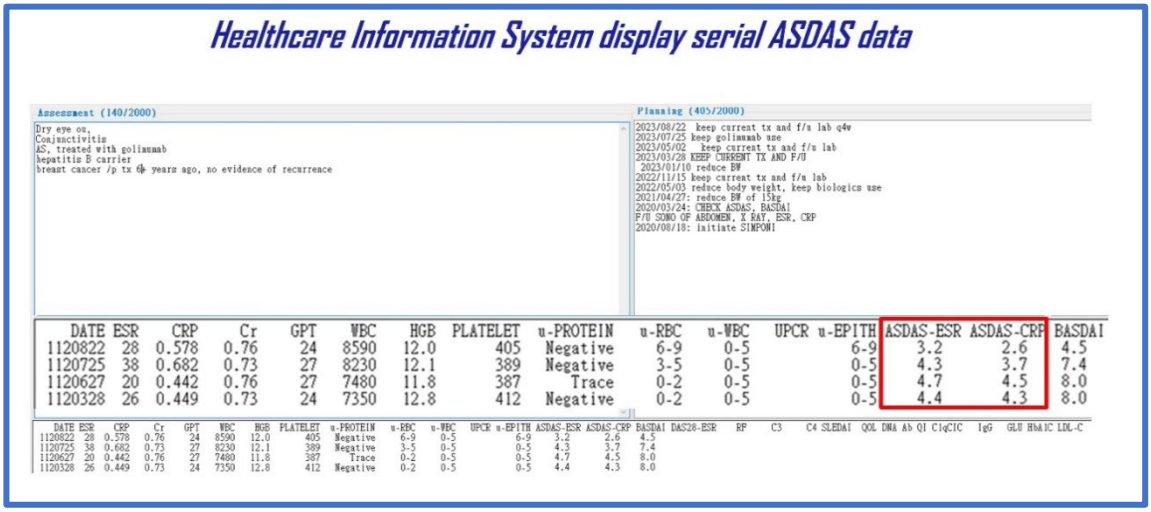

Figure 4. The automatically generated ASDAS score is displayed not only on remote device but also the healthcare information system to be assessed by the physicians.

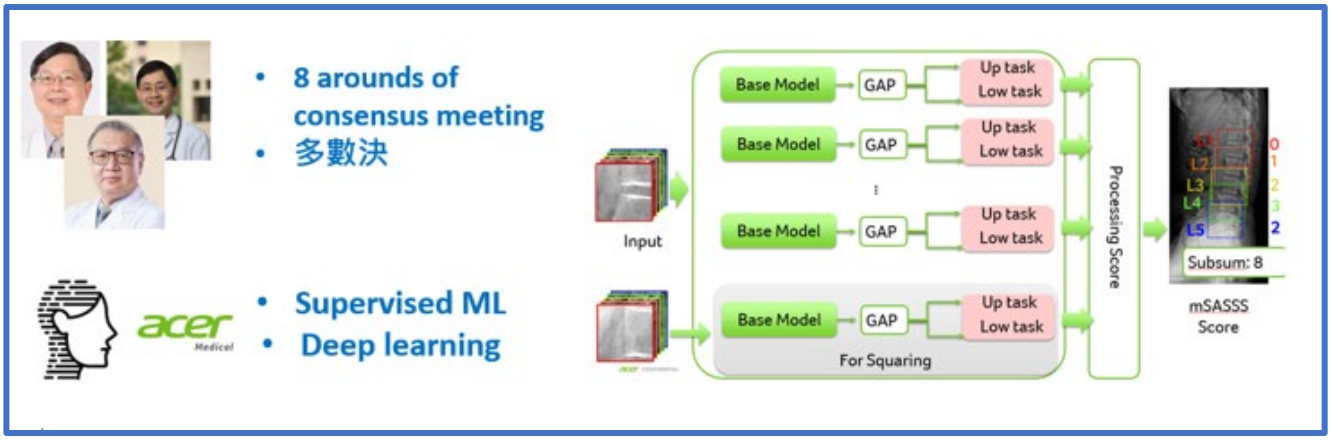

Figure 5. The co-development of AI mSASSS system by clinical physicians and information technology specialist from our hospital and Acer Medical.

Improving Adherence to the Standard of Care

Calculation of ASDAS requires data from both laboratory measurements and multiple PROs. The calculation of mSASSS involved interpretation of the radiographic change of 12 spinal columns which is not only used in clinical trial as an ultimate outcome but is also suggested to be routinely used in clinical setting. However, the laboring process of calculation of ASDAS and mSASSS has limited their use in everyday clinical practice.

After the implementation of these two systems, we were able to frequently assess patients' ASDAS score. The cumulative numbers of patients being assessed reached 1516 at the end of 2023 (Figure 6). To compare with other medical centers around the world, systemic review of scientific articles regarding disease activity score in ankylosing spondylitis was searched. The result showed TCVGH had the largest numbers of patients being assessed with ASDAS (Figure 7). Furthermore, the AS-assisted mSASSS assessment system enabled a quick, convenient and reliable reporting mSASSS scores (Figure 8). It takes about 12 minutes to get the reporting of mSASSS after radiographic image examinations.

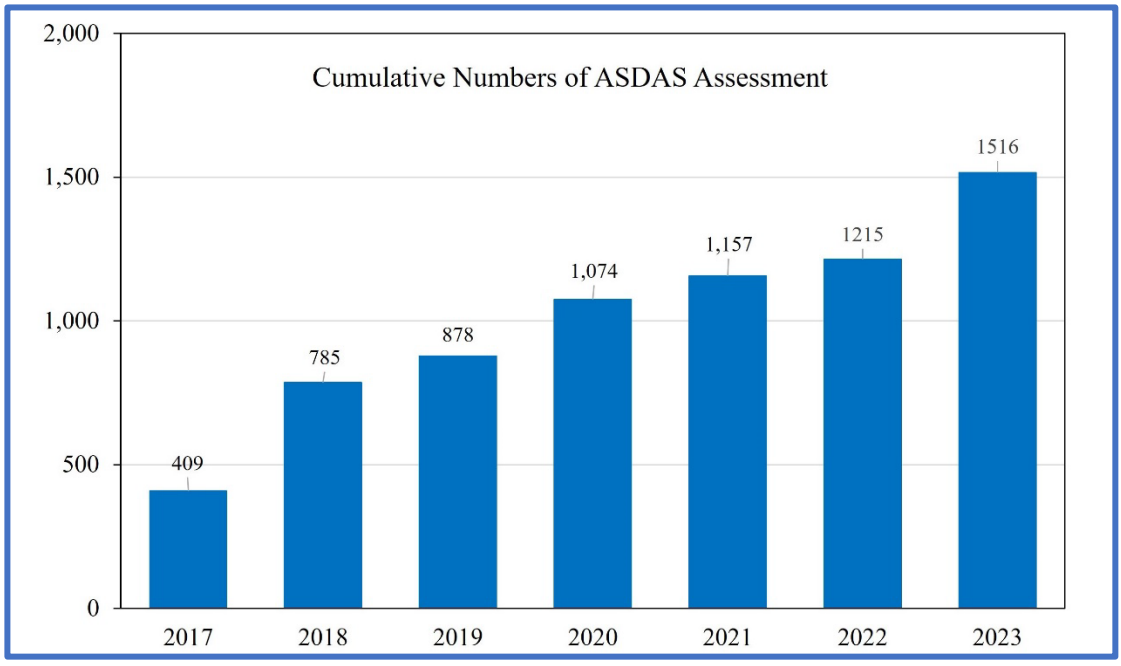

Figure 6. The cumulative numbers of patients using electronic medical record management system to assess ASDAS score.

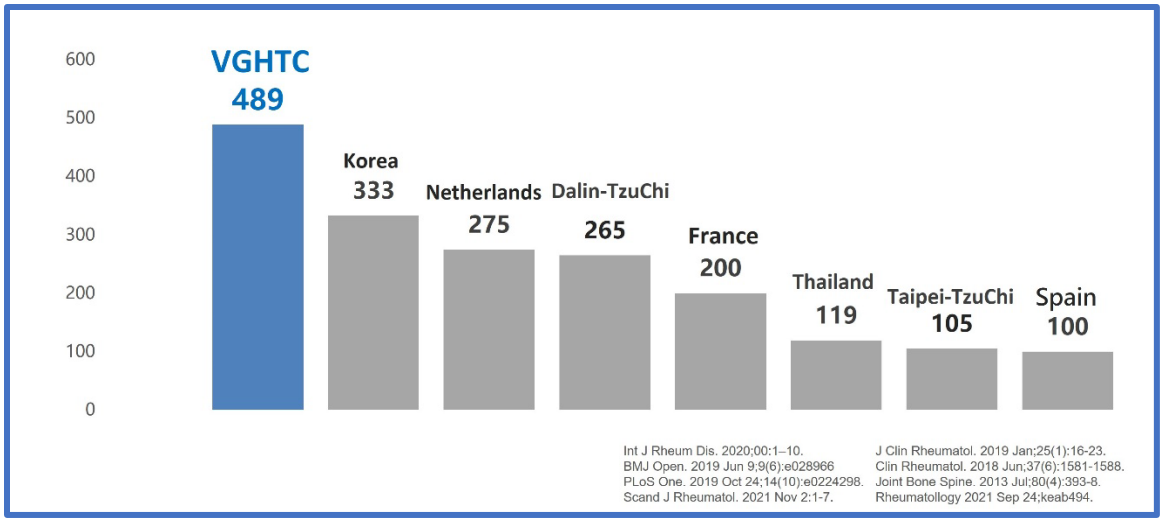

Figure 7. Comparison of numbers of ASDAS assessment among single medical centers around the world.

Figure 8. Example of the automatic calculation of the mSASSS score.

Improving Patient Outcomes

The treatment target of disease activity in patients with AS is to achieve a ASDAS score of less than 1.3, which is considered as an inactive disease status. The proportion of inactive disease in AS patients at TCVGH after the implementation of the EMRMS reached 42%, which is superior to published data from all other medical centers around the world (Figure 9). The average duration of each outpatient visits shortened 0.7 minutes in patients with inactive disease activity, reflecting the enhanced healthcare efficacy with the help of the system (Figure 10). Furthermore, the incidence of chronic kidney disease (CKD) decreased after implementation of the EMRMS, probably due to timely adjustment of treatment based on ASDAS data (i.e., regular assessment of disease activity facilitate rheumatologists to timely reduce of the dosage of non-steroidal anti-inflammatory drugs (NSAIDs) that may cause kidney damage in patients with high disease activity by early use of biologics, and in patients with persistently inactive disease) (Figure 11 and figure 12).

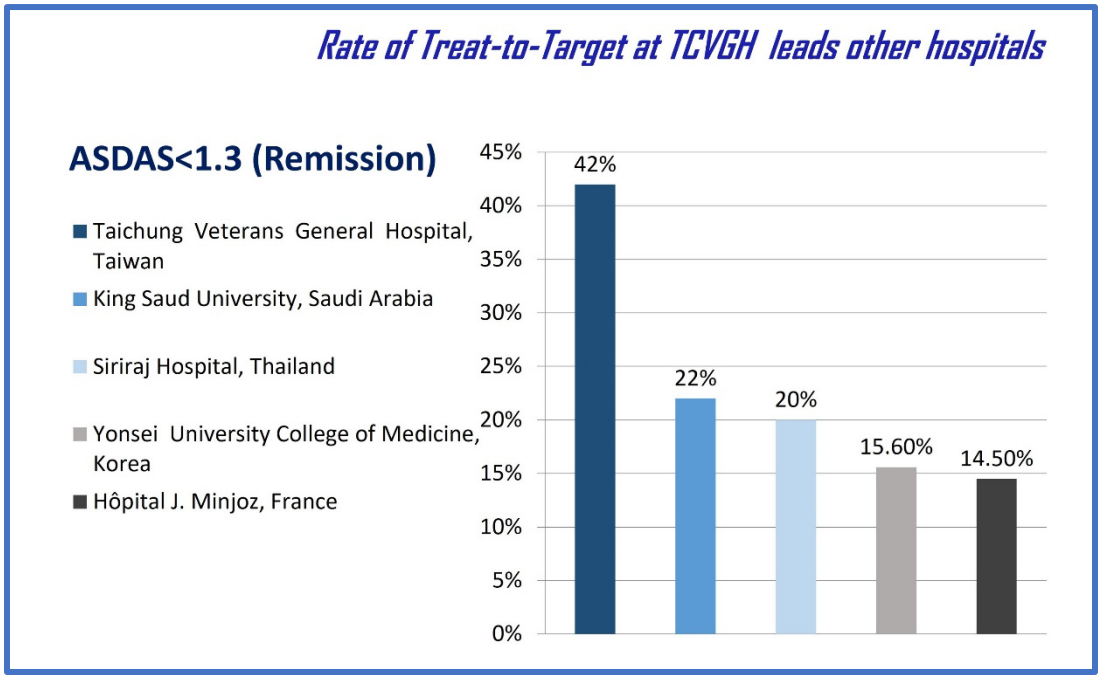

Figure 9. The complete remission rate in TCVGH compared to other medical centers around the world.

	Inactive Disease Activity			Low Disease Activity			High Disease Activity			Very High Disease Activity		
Outpatient Time	Previous Year	Next Year	P	Previous Year	Next Year	P	Previous Year	Next Year	P	Previous Year	Next Year	P
	9.2 ±4.2	8.5 ±3.3	0.022	9.3±4.8	9.0±4.4	0.278	8.7±4.1	8.5±3.4	0.554	9.6±4.1	9.8±4.1	0.827

Figure 10. The average duration of visits in different patient subgroups.

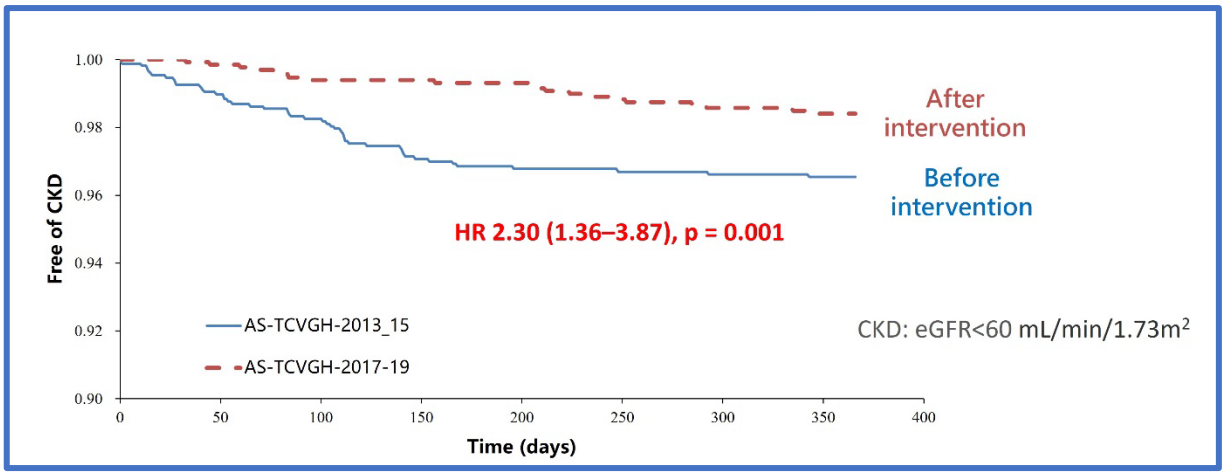

Figure 11. The chronic kidney disease free rate before and after the implementation of the electronic medical record management system.

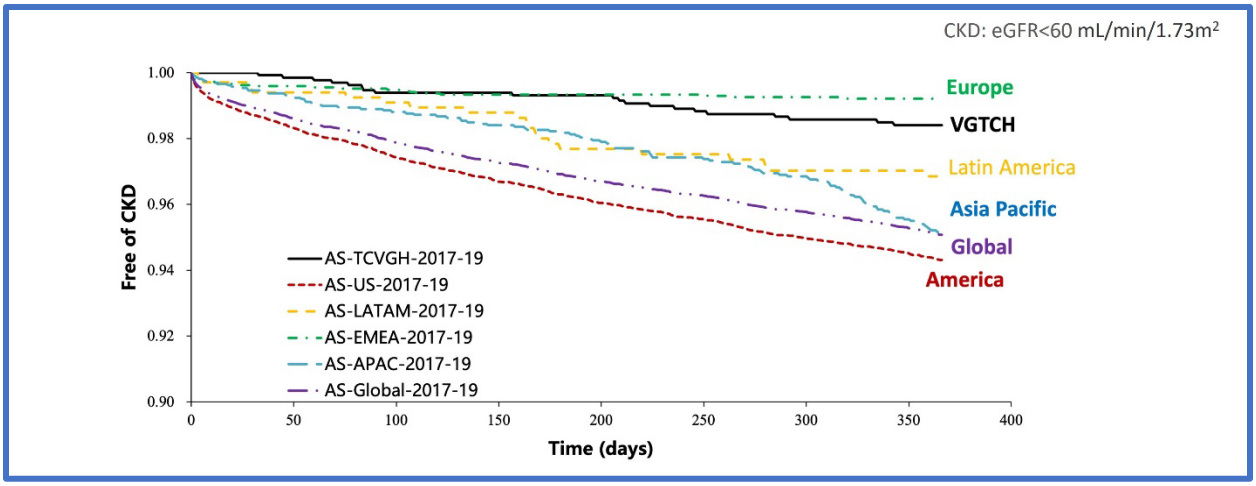

Figure 12. The chronic kidney disease free rate at VGHTC and around the world.

Accountability and Driving Resilient Care Redesign

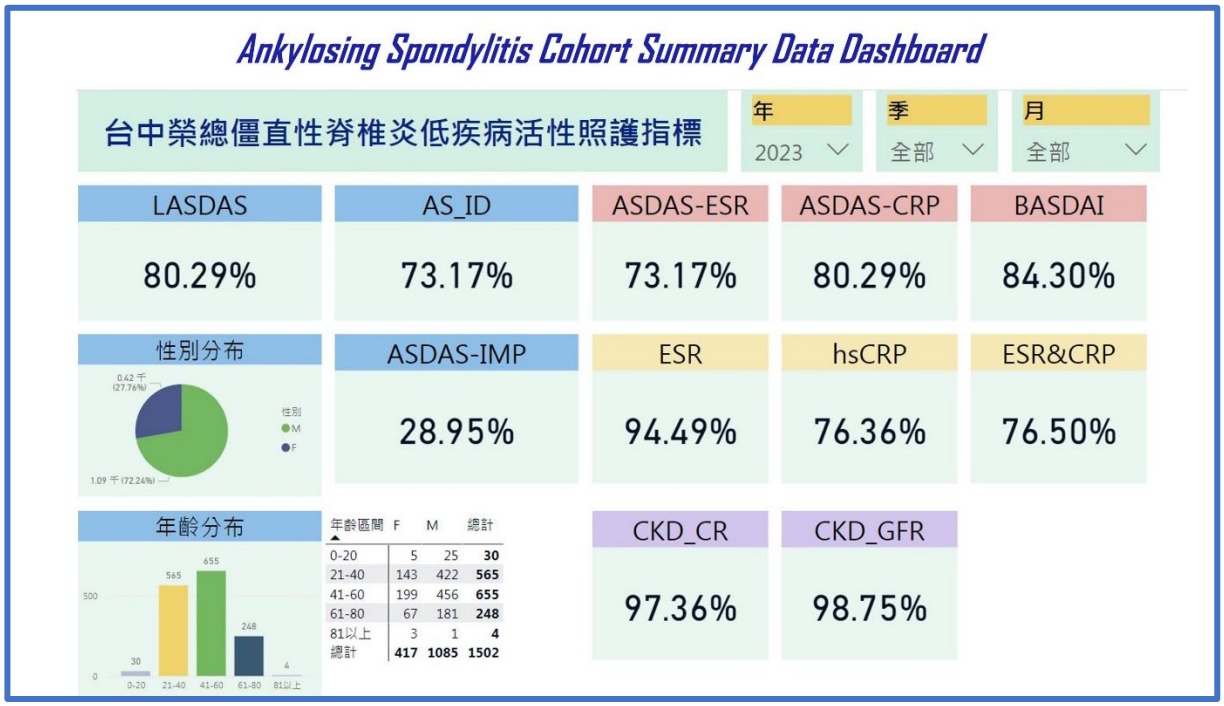

Figure 13. A real time summary dashboard was designed to visualize not only the characteristics of our cohort but also the overall disease control status.

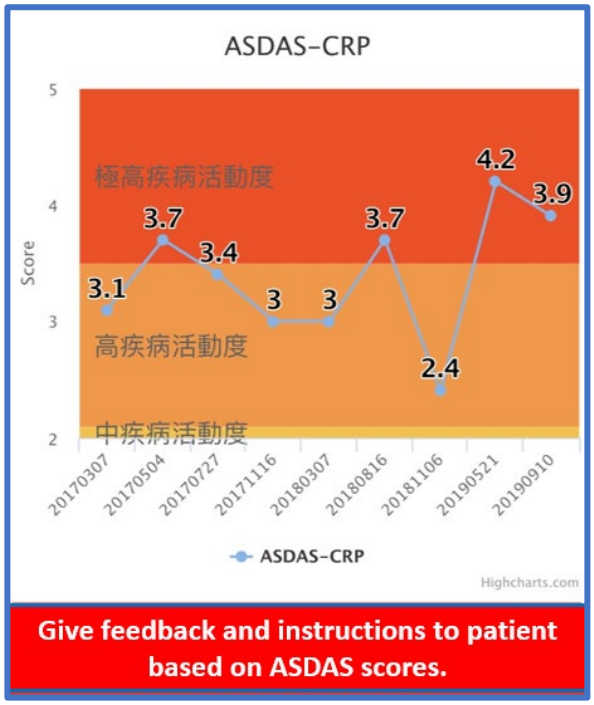

Figure 14. Timely Feedback and medical advice to the patients based on the ASDAS scores.

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HIMSS Global Conference Audience Guidance

Topic Guidance: Check three which apply to this case study

✓Clinical Informatics and Clinician Engagement

Clinically Integrated Supply Chain

✓Consumer/Patient Engagement and Digital/Connected Health

Consumerization of Health

Culture of Care and Care Coordination

Data Science/Analytics/Clinical and Business Intelligence

Disruptive Care Models

Grand Societal Challenges

Health Informatics Education

Health Information Exchange

Interoperability

Data Integration, and Standards

✓Healthcare Applications and Technologies Enabling Care Delivery

Healthy Aging and Technology

Improving Quality Outcomes

Innovation, Entrepreneurship, and Venture Investment

- Leadership, Governance, and Strategic Planning
- Population Health Management and Public Health
- Precision Medicine and Genomics
- Process Improvement, Workflow, and Change Management
- Social, and Behavioral Determinants of Health
- Telehealth
- User Experience (UX)
- Usability
- User-Centered Design