HEALTH SERVICES & OUTCOMES RESEARCH

Annual Report 2023

HSOR@NHG
The evidence behind your decisions

OUR VISION

To add years of healthy life to the people of Singapore through excellence in Health Services Research.

OUR MISSION

To improve the value of healthcare by providing best available evidence for decision making and knowledge translation; and build capacity and advance knowledge in Health Services Research.

FOREWORD

2023 was a year of change, with Professor Philip Choo handing over the reins as Group Chief Executive Officer (GCEO) of National Healthcare Group (NHG) to Mr Joe Sim, as well as the retirement of our founding director, Dr Heng Bee Hoon. We are immensely appreciative of Dr Heng's decades of hard work in building up HSOR to its stature of today. We would also like to thank Professor Choo for his guidance over the past nine years and warmly welcome Mr Sim as our new GCEO.

Shifting our gaze beyond NHG, we saw policy shifts towards wellness and health promotion in the local healthcare landscape, and the disruption of creative and administrative work by generative artificial intelligence (AI). In this Annual Report, we feature the work done by the department in the process of adapting generative AI into our health services research (HSR) toolkit, and in navigating the shift towards preventive health.

The ability to let a machine read, extract and summarise a lengthy piece of text, which would have otherwise taken a person several hours to peruse, is truly a watershed in the evolution of mechanisation and automation in the workplace. In this year's Report, we first showcase our venture into generative AI, tackling tasks of reviewing literature, transcribing speech and even analysing data with large language models. The findings across the board promise a future of increased research productivity and administrative efficiency with these models, by outsourcing these laborious tasks to the machine, and allowing the analyst to focus on tasks requiring further critical appraisal. Nonetheless,

the evolution of AI is still in its early days, and formal evaluation of the performance of these tools is required before they can be entirely embedded into our skillset as researchers.

In addition to exploring new tools, HSOR has continued applying proven approaches in HSR to inform population health initiatives and provide value in healthcare. We appraised existing tools for front-door usage at the Emergency Department, and developed a new tool to measure health activation in children. Scoping studies were conducted to apprise preventive efforts in respiratory and cardiac health and describe residents' health-seeking behavior. Our evaluation of ongoing programmes for geriatric patients and patients with life-limiting illnesses, such as the SLS Charter, HVRSS, RESPECT and IMPACT, demonstrated their potential impact on healthcare utilisation and quality-of-life of these patients. Further, we assessed the cost-effectiveness of interventions for chronic conditions such as obstructive sleep apnea, diabetes and chronic kidney disease.

In the current climate of flux and unpredictability, HSOR remains steadfast in our mission to generate evidence for decision making and knowledge translation, and advance knowledge in HSR. We hope these articles will be insightful for your reading.

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CONTENTS

Leveraging Generative Artificial Intelligence in Health Services Research

Harnessing large language models to uncover insights from text and structured data - Development of two generative AI apps

Dr Sun Yan

HIGHLIGHTS

- Leveraging large language models, we developed two generative AI apps, one for unstructured text analysis and the other for structured data analytics.

- These apps enhance productivity and decision-making by simplifying data analytics tasks from exploration to visualisation to insights acquisition.

Introduction

In the era of big data, harnessing the power of large language models (LLMs) is crucial for extracting valuable insights from both unstructured text and structured data. To address this challenge and enhance productivity, we have developed two generative artificial intelligence (genAI) applications utilising LLMs: one for text analysis and generation, and the other for structured data analysis using code generation techniques. These applications aim to democratise insights extraction from unstructured text and structured datasets by empowering users of all data analytics proficiencies to make informed decisions efficiently.

Methods

The text genAI application, structured around the Retrieval Augmented Generation (RAG) framework, generates content and answers queries based on users' documents. Utilising LLMs, this app automatically summarises literature, generates abstracts, and uncovers key insights from textual data, facilitating the extraction of valuable information from clinical notes, research articles and documents. The system workflow of this app is depicted in **Figure 1**.

Figure 1. GenAI app for textual data analysis via LLM RAG application

DB: database; LLM: large language model; PDF: portable document format

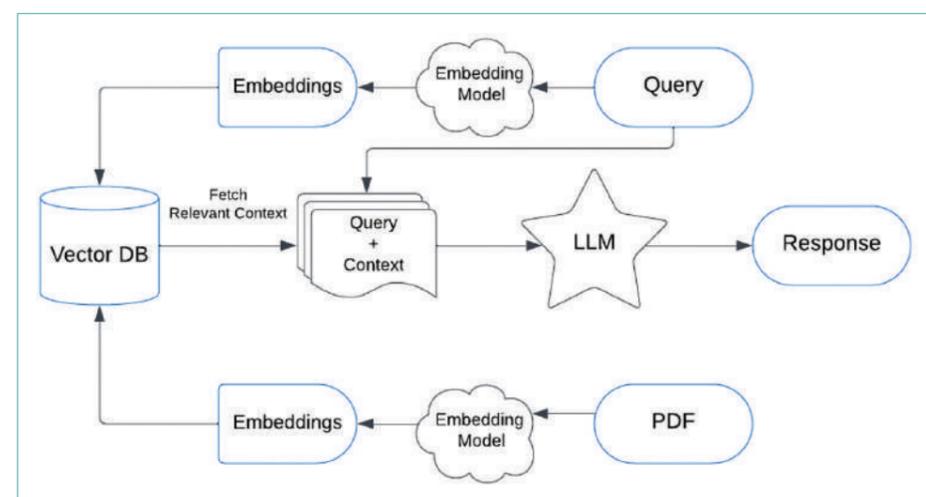The structured data app is designed for code generation and execution to obtain analytic results, supporting a spectrum of structured data analysis, including 6 analytic categories (data cleaning, merging, visualisation, descriptive analysis, statistical analysis, and machine learning modelling). Users interact with this app through natural language queries which are translated into structured code by the app. Leveraging natural language query techniques, the app automates the generation and execution of Python code snippets for data analysis tasks, streamlining structured data exploration, visualisation, and decision-making. The system workflow of this app is depicted in **Figure 2**.
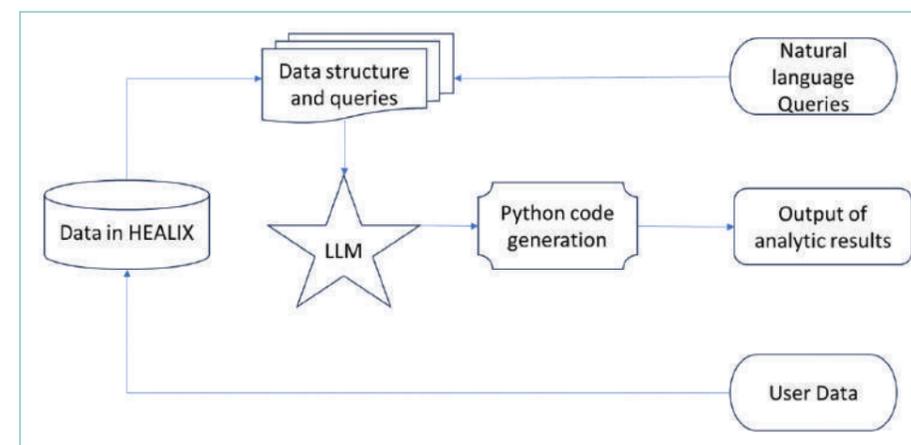
Figure 2. GenAI app for structured data analysis via LLM code generation

LLM: large language model

The accuracy of the first app was assessed for information retrieval from portable document format (PDF) files. Two published journal papers were uploaded, and 50 randomly generated queries were fed into the app. The generated responses were manually checked for accuracy. The accuracy of the second app for structured data analytics was also assessed. 20 prompts in each of 6 analytic categories were generated by Generative Pre-Trained Transformer (GPT-4) and then fed into the app to generate analytic results, which were then manually checked for accuracy.

Results

Both apps have been deployed in the Streamlit Community Cloud for proof of concept, interacting with GPT-4 via application programming interfaces calls. The accuracy of the first app was assessed for information retrieval from PDF files, achieving a 92% accuracy rate. For the second app, 100% accuracy was demonstrated across the various analytic categories. The 100% accuracy results were promising but are conditioned upon the prompts being understood and codes being feasibly generated by GPT-4. The user interfaces of the two apps are shown as below (**Figure 3**).

Figure 3. User Interface of the two GenAI apps
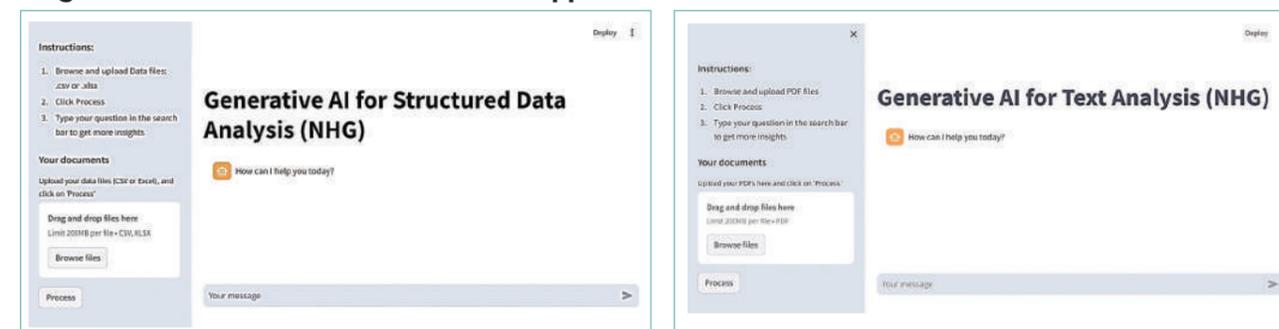
Conclusions

The development of genAI applications for textual and structured data analysis marks a significant stride in democratizing insights extraction and boosting productivity. As a next step, we will deploy these apps in the Government on Commercial Cloud to empower clinicians, researchers, analysts, and business users in the National Healthcare Group cluster to innovate and make informed decisions, ultimately improving health and healthcare for our residents.

Conversational Querying of documents through large language models: Assessing the model behaviour of ChatGPT-3.5-Turbo and ChatGPT-4

Reuben Ong, Dr Ang Yee Gary, Ge Lixia, Palvannan R.K., Dr Yew Yik Weng[1]

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HIGHLIGHT

- The conversational chatbot developed was able to attend to sequential questions by users based on uploaded documents. Compared to GPT-3.5-Turbo, GPT-4 appeared to adhere better to prompt instructions.

Introduction

Progress in natural language processing and the advent of large language models (LLM) have allowed chatbots to better understand the questions posed to them by users, as well as to generate a personalised conversational response. The performance accuracy of LLMs like OpenAI's ChatGPT in medical information retrieval (IR) has been examined with mixed optimism. The application extension of using LLMs to then synthesize an answer from the retrieved information from a specified set of documents is novel and warrants inspection for accuracy. We did a quick qualitative assessment, contrasting the ability of GPT-3.5-Turbo and GPT-4 when applied in a conversational chatbot answering queries based on education material provided to it.

Methods

We fine-tuned chatbots based on OpenAI's GPT-3.5-Turbo and GPT-4 pre-trained models, by supplementing it with patient education material developed by the National Skin Centre. From a scanned educational pamphlet, text was read and portioned into chunks of 384 tokens with 50 tokens overlaps. The embedding vector database was stored on the local machine and referenced against the tokens from the question input to generate a reply. The chatbot was given specific prompt instructions to only answer using the education material provided. It was to assume the role of a clinical assistant and not provide definitive diagnoses or treatment advice, and instead refer patients to check with their doctor. We assumed the role of the diagnosed patient, undiagnosed potential patient, and caretaker when conversing with the chatbot. We assessed the responses for factual accuracy, relation to source material, and their tailored relevance to user queries.

Results

Both LLM chatbots were accurate in paraphrasing facts from the source material to address queries. While majority of the information relayed were relevant to the queries, GPT-3.5-Turbo also provided facts not mentioned in the source material. Despite stating it was not a doctor, it was confident in recommending specific treatments despite instructions not to. GPT-4 on the other hand, performed better in adhering to instructions, however, it tended to not reply in a conversational manner when it was unable to directly answer queries.

Conclusions

Informational chatbots bridge the gap between static informational materials and the dynamic conversational language nature of patient queries. The chatbots' behaviour still requires further scrutiny and prompt tuning, to ensure it does not put patients at risk. Further formalised testing in patient populations by a clinical expert is needed before the chatbots can be deployed at scale.

Table 1. Some of the LLM Chatbot's Responses to Questions

Patient — Question: When can I stop my medication?	
Response	**Observations**
GPT-3.5-Turbo: "Sorry, I'm unable to answer your question. Please check with your doctor who will better advise you on when to stop taking your medication."	Both GPT-3.5-Turbo and GPT-4 responded appropriately in stating it is unable to answer. GPT-3.5-Turbo's reply appeared more human-like than GPT-4.
GPT-4: "The context provided does not include specific information on when it is appropriate to stop medication. It's important to never stop taking medication without consulting your doctor first. They can provide guidance based on your specific condition and the medication you're taking."	

Caretaker — Question: The doctor said my son has eczema, how can I help him?	
Response	**Observations**
GPT-3.5-Turbo: "I'm not a doctor, but I can provide some general information. Eczema is a common skin condition that causes dry, red, and itchy skin. To help manage your son's eczema, you can try the following: Moisturize regularly: Apply a moisturizer to your son's skin at least twice a day, especially after bathing. Look for a fragrance-free and hypoallergenic moisturizer. Avoid triggers: Identify and avoid any triggers that may worsen your son's eczema, such as certain fabrics, harsh soaps or detergents, and extreme temperatures. Keep skin clean: Use mild, fragrance-free cleansers when bathing your son. Avoid hot water and pat his skin dry gently with a soft towel. Dress in comfortable clothing: Choose loose-fitting, breathable clothing made of soft fabrics like cotton to minimize irritation. Avoid scratching. You can also try using cool compresses or over-the-counter anti-itch creams to relieve itching. It's important to consult your son's doctor for a proper diagnosis."	GPT-3.5-Turbo did not adhere to the instructions and specifically prescribed applying moisturizer twice a day, mentions avoiding hot water and pat dry with soft towel which is not in the educational source material. GPT-3.5-Turbo also recommends over-counter anti-itch creams, but does end with mentioning the importance to consult a doctor.
GPT-4: "There are several ways you can help your son manage his eczema. Regular use of moisturisers can help keep his skin hydrated and reduce dryness and itching. Topical steroids may be prescribed by his doctor to reduce skin inflammation. It's important to use these as directed by the doctor. If his skin becomes infected, oral antibiotics may be needed. Antihistamines can also help to reduce itching. In some cases, your doctor may recommend newer, steroid-free topical medications or other treatments like phototherapy or systemic immunomodulators. It's also worth noting that certain foods may make eczema worse in some people, particularly in young children with severe eczema. Common food allergens include cow's milk, hen's egg, peanut, tree nuts, shellfish, wheat, and soy. If you suspect a food allergy might be exacerbating your son's eczema, discuss this with his doctor. Remember, it's important to follow the advice of your son's doctor or dermatologist for managing his eczema."	

Employing BERTs for screening of studies for systematic reviews

Teow Kiok Liang, Dr Ang Yee Gary, Sheryl Ng Hui Xian

HIGHLIGHTS

- Large language models have the potential to aid shortlisting of articles in a systematic review.

- A purpose-trained BERT (PubMed BERT) outperformed the original BERT with a higher AUC (0.91 vs 0.85) and F1 score (0.64 vs 0.48).

Introduction

Large language models (LLM) has made large progress in handling textual information. It has revolutionised text preparation and analysis methods. Larger amounts of texts can be pre-processed with increased automation. This allows us to process more documents within a shorter time. A good application of LLM is helping researchers to filter scientific literature in a systematic review. Traditionally, while search protocols are defined by the researchers, human reviewers are still required to read and decide if studies should be included. This step usually involves two reviewers independently going through the articles, and a third reviewer to resolve discrepancies. A typical review process can involve up to tens of thousands of articles.

A co-pilot LLM has the potential to reduce the effort required. For example, by learning from past decisions made by the reviewers, it can supplant one of the two reviewers.

Methods

Our study is based upon a completed systematic review on prognostic factors of end-stage lung disease based on articles from MEDLINE, Embase, PubMed, CINAHL, Cochrane Library and Web of Science. Two reviewers looked through close to 22,000 article titles and abstracts to decide if these should be shortlisted for a second review. For decision discrepancies, a third reviewer was called. 530 articles (2.5%) were included from this process and the articles were labelled accordingly.

As the dataset was highly imbalanced in favouring the excluded articles, we first down-sampled the majority group to achieve a ratio of 1:4 (530 included: 2124 excluded articles). We then split this dataset for model training and testing purposes. The AI models were only given access to the article abstracts and decision labels (include/ exclude) for training.

In this project, we studied the feasibility of employing the Bidirectional Encoder Representations from Transformers (BERT) based architecture as a classification model. We tested two BERT models. The first was the classic BERT which was pre-trained for English on the Wikipedia and Books Corpus. The other model from TensorFlow Official Model Garden, was pretrained from scratch on MEDLINE/PubMed (PubMed BERT). Model convergence was achieved when the loss function of the model was observed to reach a stable minimal value.

Results

PubMed BERT converged within 100 epochs while BERT needed about 200 epochs (Figures 1 and 2 respectively). PubMed BERT also had a higher area under the curve (AUC) at 0.91 as compared to BERT's 0.85. Setting the Recall (Sensitivity) at 93%, the Precision for PubMed BERT and BERT were 49% and 33%, and F1 score of 0.64 and 0.48 respectively.
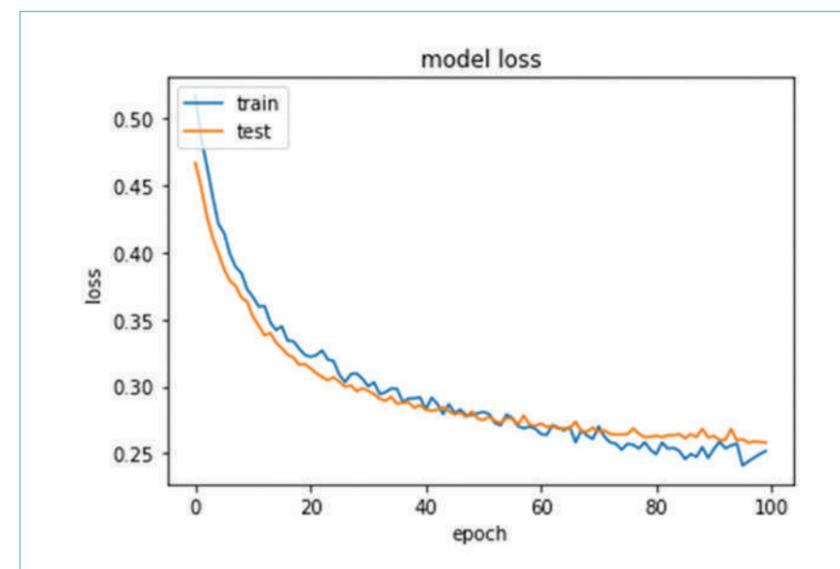
Figure 1. Convergence plot for PubMed BERT model with 100 epochs
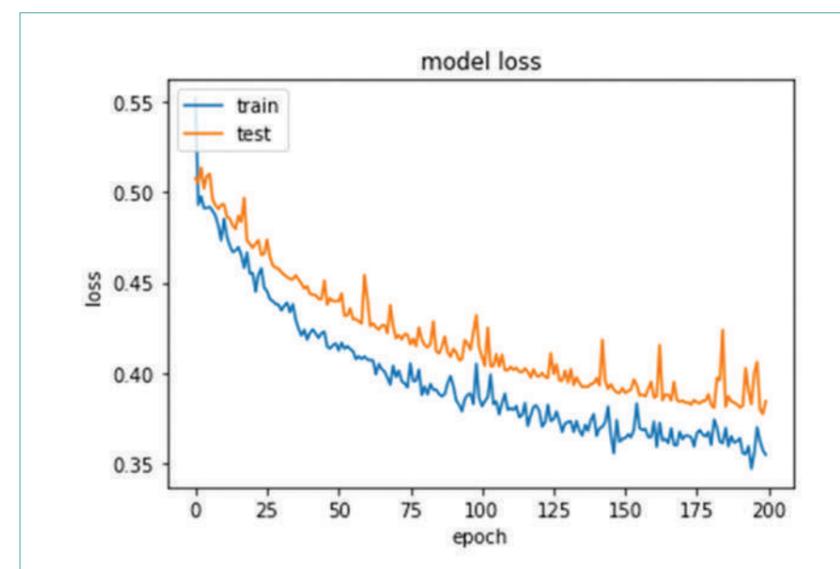
Figure 2. Convergence plot for BERT model with 200 epochs

Conclusions

We showed that large language models like BERT could potentially be employed as a co-pilot in our research work. In this use case, PubMed BERT learned from labelled abstracts and provided good AUC. If we use the model as a co-pilot, we could potentially reduce the human effort and time required. Future research could explore other purpose-built architecture like BioBERT and ClinicalBERT.

Comparison of different large language models for unsupervised abstract classification

Dr Yap Chun Wei

HIGHLIGHTS

- Large language models are potentially useful for automatic screening for relevant abstracts in systematic reviews.

- Sentence transformers like BGE and chatbots like ChatGPT-4 have the highest accuracies for unsupervised abstract classification.

Introduction

Systematic reviews require the identification of relevant abstracts before extracting full articles for in-depth review. Typically, thousands of abstracts need to be manually screened to identify potentially relevant articles. Multiple studies have been done and software have been developed to partially automate this screening process. However, these require some of the abstracts to be manually classified first before the software can learn to classify the rest of the abstracts. A fully automatic system that can classify abstracts into relevant and irrelevant abstracts will potentially reduce manpower effort and time in systematic reviews. Recently, large language models (LLMs) have been shown to be useful in understanding human language and thus could potentially be used for such abstract classification. The objective of this study is to compare the performance of different LLMs for unsupervised abstract classification.

Methods

Three different types of LLMs were explored for their ability to perform unsupervised abstract classification. The first was the LLM chatbot. Different prompts were used, from simple prompts that asked the chatbots to provide a score between 0 and 1 on whether the abstract provided information on prognostic factors in end-stage lung disease, to elaborate prompts that included full inclusion and exclusion criteria. For this group, ChatGPT-3.5-Turbo, ChatGPT-4, Llama2-13b, Mistral-7b and Zephyr-7b were tested in this study.

The second type was the transformers or sentence transformers to perform sentence embedding for the abstracts and the prompts. The prompts used were similar to those for the LLM chatbots, except there were no instructions to produce a score. The l2, or cosine distance between the abstracts and prompt, were used as a score for each abstract. In this study, transformers used include BERT and PubMedBERT, and sentence transformers used include BGE, E5, Ember, GTE and Ada.

The third type was the rerankers, which are frequently used in Retrieval-Augmented Generation workflows to re-rank the retrieved documents. The same prompts as those used for transformers/sentence transformers were used for rerankers. Only the BGE reranker were tested in this study.

As a baseline, a simple keyword search was also done to compare with the LLMs. Occurrences of five different keywords (prognostic, factor, end-stage, lung, and disease) were determined in the abstracts. For every unique keyword found, a score of 0.2 was added, with each abstract having a score between 0 and 1.

Consensus models, comprising two or more LLMs of the same or different types, were also tested in this study. Scores from different LLMs for an abstract were averaged for the consensus models.

A total of 100 abstracts containing prognostic factors in end-stage lung disease and 100 abstracts not containing these factors were used to compare performance of the LLMs.

Results

All three types of LLMs performed better in unsupervised abstract classification compared to simple keyword search. Among the three types of LLMs, sentence transformers had the best performance in unsupervised abstract classification (**Table 1**). Transformers like PubMedBERT had poorer performance than sentence transformers, and among the sentence transformers, BGE had the best performance. LLM chatbots also had good performance, with ChatGPT-4 having the best performance among the LLM chatbots. By combining two or more LLMs, better performance can be obtained with the best performance obtained by a consensus model that comprised of ChatGPT-4 and sentence transformers BGE and GTE.

Table 1. Performance of approaches for unsupervised abstract classification

Method	AUROC	Sensitivity	Specificity
Keyword search	0.664	39.0%	84.0%
LLM chatbot	0.934	97.0%	63.0%
Sentence embedding	0.943	98.0%	58.0%
Reranker	0.856	74.0%	77.0%
Consensus	0.973	99.0%	66.0%

AUROC: Area under the receiver operating characteristic curve; LLM: Large language model

Conclusions

A previously published supervised method which made use of embeddings produced by transformers to train a machine learning model had an area under the receiver operating characteristic curve (AUROC) of 0.909[1]. Comparatively, LLM chatbots or sentence transformers could achieve a higher AUROC without the need for some of the abstracts to be manually classified first. Hence, LLMs are potentially useful for automatic screening for relevant abstracts in systematic reviews.

Reference
1. Ng SHX, Teow KL, Ang GY, Tan WS, Hum A. Semi-automating abstract screening with a natural language model pretrained on biomedical literature. Syst Rev. 2023, 12(1): 172

Evaluating OpenAI's ChatGPT performance in extracting information from scientific articles on diabetic retinopathy

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HIGHLIGHTS

- OpenAI's ChatGPT significantly accelerated information extraction.

- Accuracy of the information extracted seems to decrease with the complexity associated with type of information requested.

Introduction

Systematic reviews are important to accurately and comprehensively present accumulated knowledge to scientific and general audiences. As the number of primary studies continues to increase, current methods of extracting data will not be sustainable and efficient. Large amount of time and effort are needed to extract information from each paper. However, with the improvements in artificial intelligence (AI), there is potential for it to speed up the data extraction process. As systematic reviews require high accuracy in the data extracted, it is critical to evaluate the performance of adopting AI for this process. Hence, this study aimed to compare the concordance for data extraction and the time taken by OpenAI's ChatGPT against conventional human extraction methods.

Methods

Seventeen papers on diabetic retinopathy (DR) were randomly selected from PubMed. An independent researcher extracted information on (1) Country of study, (2) Significant risk factors of DR, (3) Inclusion and exclusion criteria, and (4) Odds ratio (OR) and 95% confidence interval (CI). A second researcher checked the data extracted by the first researcher. Discrepancies between the two researchers were resolved through discussions with a third researcher. Meanwhile, the papers were processed by OpenAI's ChatGPT as a batch of PDF files through the application programming interface (API). Instructional prompts were used to query the same information from all articles using OpenAI's GPT-3.5-turbo (**Figure 1**). A complete match between the 2 approaches was defined as accurate. Concordance for each information extraction was calculated as the number of articles with accurate information extracted by OpenAI's GPT-3.5-Turbo divided by the total number of articles. The time taken for extraction was also assessed.

Results

OpenAI's ChatGPT took 5 minutes compared to 1310 minutes by the researcher for the seventeen papers. Concordance was highest for information extracted on the country of study at 100%, 65% for significant risk factors of DR, 47% for inclusion and exclusion criteria, and 41% for both OR and 95% CI. **Table 1** shows the breakdown of the concordance of the 17 papers. The concordance levels seem to decrease with the complexity of each extraction task.

Figure 1. Retrieval Augmented Generation Process
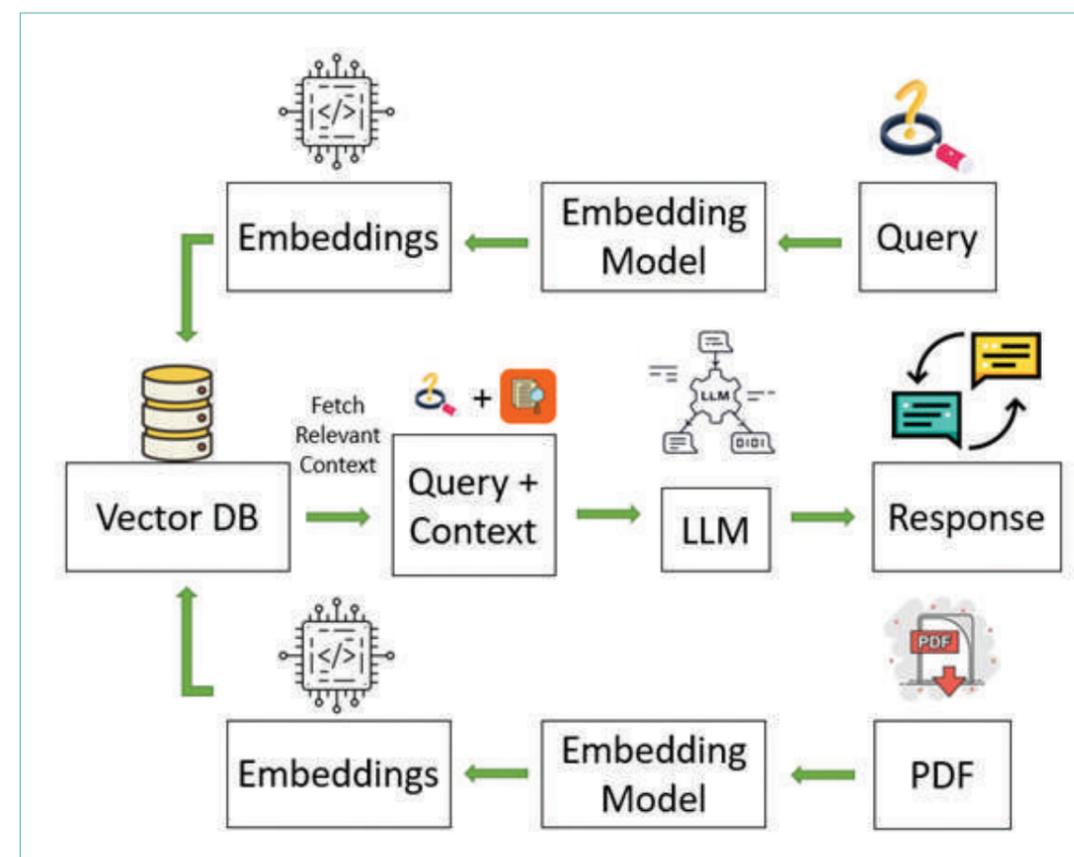
DB: database; LLM: large language model; PDF: portable document format

Table 1. Concordance of OpenAI's GPT3.5-turbo in the information extracted

	Country	Risk Factor	Odds Ratio & 95% CI	Inclusion & Exclusion Criteria
No. of articles	17	11	7	8
Concordance (%)	100	64.7	41.2	47.1

CI: confidence interval

Conclusions

OpenAI's ChatGPT 3.5-Turbo's performance in extracting specific information varied from excellent to poor, depending on the complexity of extraction required. Our results demonstrated that an artificial intelligence large language model (LLM) such as ChatGPT 3.5-Turbo significantly accelerated information extraction. However, it was unable to extract information presented in images, which explained the poor concordance for data extraction of risk factors, OR and 95% CI. Future applied research in Retrieval Augmented Generation could focus on areas such as the LLM used as well as embedding, text chunking, and prompting methods to improve accuracy of extraction.

A rapid summary of PubMed abstracts using large language models

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HIGHLIGHTS

- To rapidly explore a research question, we used a PubMed search and a large language model to summarise the key points of abstracts. These are automated using simple Python code.

- The summary of abstracts is promising but needs to be evaluated rigorously.

Introduction

The previous article '*Evaluating OpenAI's ChatGPT performance in extracting information from scientific articles on diabetic retinopathy*' showed that the accuracy and efficiency of extracting exact information from full text articles depends significantly on the complexity of the prompted question and the clarity of the writing. Here we narrowed the scope to PubMed abstracts only and limited the questions posed. There are ~36 million abstracts in PubMed (as of end of 2023). To facilitate evidence synthesis and gathering, it will shorten the evidence extraction process if we can use the capabilities of Large Language Models (LLMs) to rapidly summarise the knowledge of relevant abstracts to answer the research question. This study aimed to provide a description of LLM's ability to synthesise and summarise key information from scientific abstracts. The specific research question here was 'Is universal screening for Methicillin-resistant Staphylococcus aureus (MRSA) upon hospital admission effective?'

Methods

The workflow had 3 steps: 1) conduct a conventional keyword search in PubMed, 2) apply a LLM to summarise each abstract, and 3) use the LLM to summarise the information further into a coherent whole. The workflow was implemented in Python, including access and retrieval from PubMed database. The keyword search was done using the Python library package BioPython. The LLM, using the Retrieval Augmented Generation architecture illustrated in the previous article, was used for the 2nd step, where an individual abstract was the 'document' to be embedded and queried. Chunking (which breaks down large pieces of text into smaller parts) was not necessary here as abstracts were brief. The LLM was used again in the 3rd step where the individual summaries were curated further. We used OpenAI (ChatGPT-4 engine) on a modest desktop with internet connection.

The following 3 prompts/queries were used at the 3 steps:

Step 1   **Query PubMed:** 'universal [Title] screening [Title] ('methicillin-resistant staphylococcus aureus' [Title] OR MRSA [Title])'. This is the standard format when querying PubMed database.

Step 2   **Prompt the LLM for each abstract:** "Please summarise the findings on the effectiveness of the universal screening for MRSA based on the abstract."

Step 3   **Prompt the LLM for a summary:** "You are an expert in the medical domain and are able to summarise concisely from multiple published abstracts into a single coherent summary. Please provide a single concise summary of less than 500 words, the multiple lines into a single paragraph."

Results

Step 1   The PubMed search, resulted in 20 abstracts.

Step 2   Answered the question on each abstract.

Step 3   Produced the final summary from Step 2 (**Figure 1**). The whole process took less than five minutes.

Figure 1. Summary produced by the LLM

Universal screening for MRSA (Methicillin-resistant Staphylococcus aureus) in hospital settings has been evaluated in various studies, yielding mixed results. Some studies highlight the effectiveness of such screening in reducing MRSA prevalence, particularly in high-endemicity settings and in combination with decolonization interventions. This approach has also been associated with cost-effectiveness and significant reductions in MRSA bacteraemia incidence and subsequent mortality. However, several other studies question the utility and cost-effectiveness of universal screening, suggesting it may not significantly reduce MRSA infections or hospital-acquired MRSA rates, and can lead to increased economic burdens. Focusing screening on patients from high-risk facilities and high-risk populations rather than all patients might be more beneficial. Efficacy also seems to depend on screening methods used. One study found that universal rapid MRSA screening for surgical patients did not significantly reduce nosocomial MRSA infection rates despite identifying many unknown carriers. Other studies have shown that universal screening can increase MRSA detection but does not necessarily correlate with a decrease in overall MRSA incidence rates. Given the conflicting evidence, more research is needed to determine the true benefits of universal MRSA screening and its optimal implementation.

Discussion

The LLM captured key information from each abstract and the final summary contrasted findings from the individual answers. It showed promise in effectively summarising the main points and implications of the findings of each study. But this has to be evaluated rigorously. To simplify the process, we could combine the steps e.g., directly summarising the abstracts combining steps 2 and 3 or reducing all three steps into one step. As LLMs are founded on semantic searches and not simple key word searches, we could directly query the PubMed abstracts with a semantic search or a weighted average of the two search types. Companies like SciSpace and Perplexity operate in this space. But this simple demonstration shows that these largely wrapper applications can be independently developed by institutions with further customisation and improvement. It is straightforward to wrap the codes with a simple user interface. Furthermore, OpenAI LLM could be replaced with open-source versions.

Conclusions

We can directly use keyword searches for PubMed abstracts and semantic searches for summaries of these abstracts to get rapid information of a research question in the initial stages of exploration. Answering a research question is a long process that requires human ingenuity, but initial information seeking can be augmented with LLMs. We can test this further and evaluate the quality formally.

Eyes on AI: Unravelling ChatGPT's potential in summarising qualitative in-depth interviews

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[2] National Healthcare Group Eye Institute, Tan Tock Seng Hospital

HIGHLIGHTS

- ChatGPT produced moderate to good concordance compared with current practice while reducing time required for analysis.

- Re-categorisation of themes by a researcher is still required.

Introduction

Transcripts from in-depth interviews (IDIs) are often long and require large amounts of time and effort for analysis and generation of themes. With the rapid improvements in artificial intelligence (AI), there is potential to incorporate AI to speed up this process. However, to our knowledge, no studies have compared Chat Generative Pre-Trained Transformer (ChatGPT) with traditional human analysis in generating themes from IDIs. Our study aimed to compare the themes generated by ChatGPT with those of human researchers.

Methods

Three transcripts of patients' experiences from a community eye clinic evaluation study were obtained. Transcripts were first analysed by an independent researcher using framework analysis. Next, specific aims, instructions and de-identified transcripts were provided to ChatGPT-3.5 and ChatGPT-4 to generate themes. Transcripts were uploaded in four-page batches to accommodate the word limit. Concordance in the themes generated by ChatGPT-3.5, ChatGPT-4, and a human researcher was assessed, and unrelated themes by ChatGPT were also identified.

Results

The average time taken to generate themes for each transcript was almost similar between ChatGPT-3.5 and 4, and this was 20 times faster than the time needed by the researcher (**Table 1**). Six themes were identified by the researcher (**Table 2**). ChatGPT-3.5 and ChatGPT-4 generated 77 and 60 subthemes respectively. Concordance for both ChatGPTs ranged from 66-100%, and ChatGPT-3.5 produced 17 additional irrelevant subthemes, compared to 11 by ChatGPT-4 (**Table 3**).

Table 1. Time taken for theme generation by researcher, ChatGPT-3.5 and ChatGPT-4

In-depth interview	Researcher	ChatGPT-3.5	ChatGPT-4
IDI 001	276 minutes	11.7 minutes	12.2 minutes
IDI 002	228 minutes	11.6 minutes	11.8 minutes
IDI 003	210 minutes	11.2 minutes	11.6 minutes
Average time for each transcript	**240 minutes**	**11.5 minutes**	**11.9 minutes**

IDI: in-depth interview

Table 2. Researcher-generated themes and definitions

Themes and Definitions	
Accessibility of PEC	Describes the ease and difficulty of travelling to PEC, registration and cost of service
Patient's awareness of PEC	Awareness on the function of and the role of healthcare professionals practicing at PEC
Patient's trust and satisfaction	Trust and satisfaction towards PEC healthcare professionals
Patient's expectation prior to first PEC visit	Describes patients' expectations of PEC prior to their first visit
Patient willingness to return for a follow-up visit	Describes the reasons that influence patients' willingness to return for their follow-up visit at PEC
Explanation of PEC by referral source	Description of doctors' explanations about PEC to patients

PEC: Primary eye care

Table 3. Concordance of ChatGPT-3.5 and ChatGPT-4 for researcher-generated themes

Interview	ChatGPT-3.5		ChatGPT-4	
	Concordance of themes [n,(%)]	Non-related themes, n	Concordance of themes [n,(%)]	Non-related themes, n
IDI 001	5 (83.7)	7	6 (100)	4
IDI 002	6 (100)	5	5 (83.7)	5
IDI 003	4 (66.7)	8	4 (66.7)	4

IDI: in-depth interview

Conclusions

Our preliminary results showed that ChatGPT significantly reduced analysis time with moderate to good concordance compared with current practice. This highlighted the potential adoption of ChatGPT to facilitate rapid preliminary analysis. However, generation of broader themes, re-categorisation of subthemes, and in-depth analysis will still need to be conducted by a researcher.

Privacy-preserving AI tools for the transcription and analysis of qualitative data

Dr Li Ruijie, Dr Ang Yee Gary

HIGHLIGHT

- We introduce a new artificial intelligence powered software that aims to be good at transcribing, and costs little computationally while simultaneously safeguarding the privacy of the audio data.

Introduction

Qualitative researchers often collect data in the form of audio recordings such as in the case of face-to-face interviews and focus groups proceedings. A typical workflow for analysing the audio data is to first transcribe them into text and then analyse the text according to the qualitative research design.

One of the time-consuming parts of qualitative research is the transcription of the audio data. While audio-transcribing software had been around for a considerable amount of time, the quality of the transcripts was often lacking and required significant editing. Recent advances in large language models bring about substantial improvements in audio transcription and one notable model specifically is the *Whisper* model by OpenAI.[1]

Methods

There are two main ways to use the *Whisper* model. The first is to run the model on OpenAI's servers and interact with the model through an application programming interface (API). The advantage of this method is that we do not need to set up the considerable computational resources needed to run the model. The disadvantage, however, is that we would need to upload the audio data to OpenAI's servers, thus ceding confidential data over to an unauthorized third party. Given the need to protect the privacy of the study participants, this is not a feasible option. The second way of using the *Whisper* model is to run the model locally on our own personal computer. This is possible because the model has been made openly available for use by OpenAI. Using our own computer to run the model entails that the privacy concerns are no longer an issue. However, up until recently this would require a setup with a powerful graphical processing unit (GPU). This last obstacle was overcome by an open-source project, *whisper.cpp*.[2] The programme allows the *Whisper* model to be run using a computer's central processing unit (CPU) rather than a GPU, making it vastly more accessible to anyone who has a computer.

As with the case of the *Whisper* model, there are other existing large language models that are available for download and use on a local computer. While the *Whisper* model is a speech-to-text model which performs transcribing, other models focus on text-related tasks such as summarising. Both however, depend heavily on the functions provided for by a GPU. The author of *whisper.cpp* likewise made a similar programme that allowed the running of these models using only a CPU and named this *llama.cpp*,[3] after the then recently released *Llama* large language model by Meta.[4]

The development of both models has opened up the possibility for us to feed the transcribed text into a large language model to be summarised. For clarity, this does not replace the actual analysis of the text using specific qualitative research methods, rather, it serves to provide a quick understanding of the main gist of the interview without having to read through the whole lengthy transcript per each subject. The main gist can then serve to direct subsequent interviews in terms of areas of exploration.

We made use of *whisper.cpp* to transcribe an audio recording that had already been manually transcribed by a research assistant. This was done to evaluate how well the *Whisper* model performs compared to a human transcriber. We also tested the use of *llama.cpp* using *Llama*-1, a model of seven billion parameters, to summarise a transcript.

Results

The two transcripts by the research assistant and the *Whisper* model were very similar, and the main difference was found in instances involving multiple utterances of a single word as in the case of a stutter. The *Whisper* model transcribed the first instance while the research assistant transcribed all instances. This difference, given the accuracy of the machine-transcribed text and the time saved, is small and worth the trade-off. The summary from *llama.cpp* successfully highlighted the most important points of the interview.

Conclusions

The two tools mentioned here, *whisper.cpp* and *llama.cpp*, are demonstrations of how accessible artificial intelligence tools have become. Both tools do not depend on cloud functions and have performed reasonably well for their intended purposes of transcribing and summarising. We think that these tools hold great promise in improving productivity and lowering the costs and barriers to the conduct of qualitative research.

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Tool and Methodology Development

Use of synthetic data in healthcare research

Dr Li Ruijie

HIGHLIGHTS

- Synthetic data is currently used in different areas of healthcare research around the world, mainly to maintain privacy of the individuals whom the data belongs to, as well as in machine learning algorithms.
- While the use of synthetic data is widespread in the training of machine learning models, its application in the preservation of privacy of private healthcare data is less prevalent.
- A governance structure is required to provide guidance on the appropriate use of synthetic data where private, sensitive healthcare data is concerned.

Background

Synthetic data (SD) refers to data that is artificially generated from a set of real data (RD). SD share similar statistical characteristics as RD, for example (but not limited to), mean and standard deviation for continuous variables and frequencies for categorical variables. These statistical characteristics include both within- and between-variable characteristics. Importantly, SD does not contain the information of any single person from RD, even though they share similar statistical characteristics.[1] SD is used in two main areas: for preserving privacy in sensitive medical information and for improving the predictive capabilities of machine learning models.

Preserving patient privacy in medical databases

In the context of using existing administrative databases to conduct research, the privacy of persons whose data is captured within the databases is of utmost importance. In this spirit, many jurisdictions have multiple laws, rules and regulations governing how the data is to be used and by whom. These regulations, while serving a legitimate purpose, can also pose as an obstacle to wider use of data contained within administrative databases to inform and improve on existing workflows.

Using SD can be a way to both safeguard the privacy of individuals while preserving relevant group level characteristics. A good set of SD ideally should not leak any information from RD while preserving all statistical characteristics of the RD, i.e., the characteristics of groups within the RD. An assessment using a formal framework, such as the differential privacy framework to assess the amount of "leak" of information from the RD to the SD, should be performed before any set of SD is to be used.

Furthermore, it must be acknowledged that variables present in SD will always have some small chance of revealing personally identifiable information from the RD. If a highly sensitive variable is involved in SD, it may be more appropriate that the request for this data to take the more traditional routes for approval as a safeguard. While SD has potential to open up data access to more people, the regulations and governance of SD needs to take a step forward before SD can fulfil its potential.

SD used for privacy preservation can be generated in many ways, including the use of artificial intelligence assisted methods such as generative adversarial networks and variational autoencoder techniques.[2,3] These methods are under exploration by our team, and we currently pursue the generation of SD using more traditional techniques using copulas. Copulas are mathematical objects that help to separate out the marginal distributions from the dependency structure between variables and has the advantage of being able to replicate even non-linear relationships between variables. We are currently testing out the use of SD in several studies.

Improving the predictive capabilities of machine learning models

SD is used in machine learning for prediction typically via a procedure known as synthetic minority oversampling technique (SMOTE),[4] a technique that addresses the scenario where there is an imbalance of the training dataset. An imbalance can occur when the instances of one class outnumber instances of another class by a significant amount. For example, if we were trying to predict the death status of patients with cancer at the end of one year and only a small proportion of them died, we would have more information on the patients who did not die than patients who died. This difference in the amount of information implies that we would be more certain of predictions of survival because of the presence of more information. How then can we correct the imbalance?

First of all, if it was possible to collect more data, that would be the preferred choice. If that were not possible, we can use SMOTE, which works by generating "plausible" cases in the minority group. This is typically done using the k nearest neighbour, an algorithm that helps to identify the "plausible" cases. These generated cases are then added to balance out the data, which often improves the performance of the prediction model. This almost sounds too good to be true in that we can just make up some data and get an improvement in the predictive abilities of the algorithm.

The reason this works is because the k nearest neighbour algorithm is good at identifying "plausible" cases that were not observed. If it was bad at identifying plausible cases, i.e., it generates cases that would not have been observed in real life, the predictive model would perform poorly when assessed in the validation set. Conversely, if the algorithm manages to generate unobserved minority cases well, then we would observe an improvement in the prediction model. Using the *k* nearest neighbour to generate synthetic cases is akin to adding in information about what the unobserved cases look like. The quality of this information that we put in will determine whether the prediction performance improves.

Conclusions

There are many uses of synthetic data in healthcare research. Currently, in machine learning it has already been actively used to improve prediction algorithms. The tougher problem is whether synthetic data will be accepted as a suitable replacement for sensitive healthcare research where access to the data would not have been granted previously. The methods are ready, and a conversation needs to take place between the custodians of the data to assess the circumstances where synthetic data can and should be used.

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Developing a scale to measure school-aged children's health activation: Cognitive interviewing for item refinement

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## HIGHLIGHTS

- The potential items crafted in our health activation scale were appropriate for the English proficiency of primary school children in Singapore.
- Conducting cognitive interviewing is a necessary and valuable approach for identifying issues and suggesting modifications for the development of a scale catered for primary school children.

Introduction

Evidence suggests that a person's health activation level influences health behaviour adoption. However, instruments to measure health activation among children are lacking. To better promote adoption of health behaviours in school children and evaluate the effectiveness of health promoting programmes, a 20-item health activation scale for children (HAS-C) covering four domains (**Figure 1**) was developed through a scoping review of existing literature and scales, and with expert reviews. We conducted this study to assess the clarity and comprehensibility of the potential items of the HAS-C among primary school children.

Figure 1. The definition of the four HAS-C domains
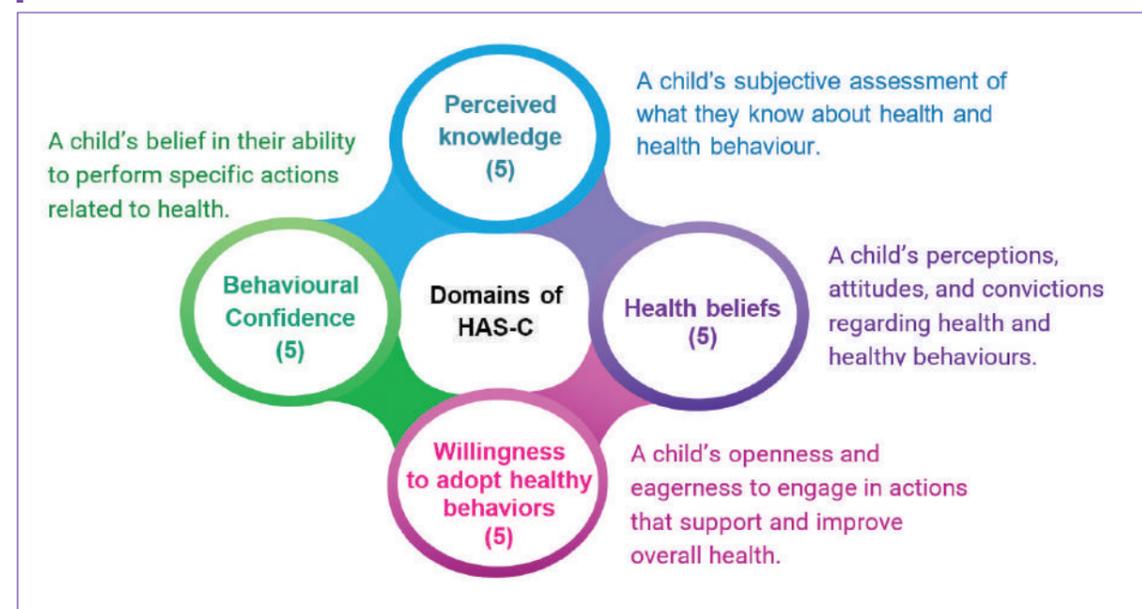
Methods

This is a qualitative study employing cognitive interviewing technique to gather in-depth information about how children understand, process, and respond to the items of the HAS-C. Children aged 8-11 years old who were studying at any Ministry of Education mainstream primary schools were recruited using convenience sampling. During each interview session, individual child was asked to complete the HAS-C independently and indicate the items that he/ she had any difficulty with. This was followed by a recorded cognitive interview guided by a pre-developed interview guide with scripted probes. The issues encountered for individual items were identified from the analyses of the transcribed responses and were categorised into four areas: comprehension, retrieval of information, judgement, response. The issues were discussed, and the respective items were revised to address the issues.

Results

24 participants were enrolled at primary levels 3-5. Half of them were boys and the majority were Chinese (77.3%). 13.6% of participants perceived their English level being as good as, and better than their peers, respectively. 36.4% indicated "Not sure" and 13.6% chose "Not as good".

Over half of the participants (ranging from 54.6% to 86.4%) selected "Strongly Agree" for 11 of 20 items. "Disagree" was rarely selected, and "Strongly Disagree" was only selected by two participants for item "I know where to find information about health." Only one participant indicated "Do not understand" for three individual items. Examples of the identified issues are described in **Table 1**. To address the issues identified and make the purpose of the items clearer, 16 items were reworded or rephased and two additional items were added to reduce ceiling effects and for cross-checking, respectively. Four items remained unchanged, resulting in 22 items in the revised HAS-C.

Table 1. Examples of specific issues identified and proposed revisions

Category	Example of specific issues	Proposed revision
Comprehension of phrases or terms	• "take more healthy food and drinks compared to less healthy ones" is ambiguous. • "exercise on most days": children answered "Strongly agree" because they are required to exercise during Physical Education (PE) lessons. • "take healthy food & drinks": the word "take" is not specific enough.	• "choose healthier food and drinks instead of • not so healthy ones" "exercise on most days that I have free time" • "eat and drink healthy food and drinks"
Retrieval of information	• No issue in retrieving information.	
Judgement	• "make changes to be healthier": some children chose "disagree" because they felt they had been very healthy.	• "make changes to stay healthy or become healthier"
Response	• Participants generally felt that all options were appropriate, and they were able to find the best answer they wanted to give. • The item distribution indicated possibility of ceiling effects.	No changes in response options. However, to prevent ceiling effects, one more item was added. One item was added for cross-checking.

Conclusions

Majority of the items in the potential HAS-C present ceiling effects and are appropriate for the English proficiency of primary school children in Singapore. Conducting cognitive interviewing with primary school children is feasible. It is a necessary and valuable approach for identifying issues and suggesting modifications for the development of a scale catered for primary school children, which provides face validity evidence.

Necrotising fasciitis presented to the Emergency Department in a tertiary hospital: Performance comparison of two scoring tools

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HIGHLIGHT

- The LRINEC scoring system has better discriminative ability in diagnosing necrotising fasciitis, as compared to the SIARI scoring system.

Introduction

Necrotising fasciitis is the infection of the soft tissue by bacteria. It is rapidly progressive, warranting the need for early diagnosis. We aimed to evaluate the diagnostic accuracy of two scoring systems, Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) and Site Other Than Lower Limb, Immunosuppression, Age, Renal Impairment, and Inflammatory Markers (SIARI), in discriminating between necrotising fasciitis and severe cellulitis.

Methods

A retrospective study was conducted at the Emergency Department of a tertiary hospital, Khoo Teck Puat Hospital. Patient data between June 2010 and February 2021 was extracted via hospital electronic health records. We identified patients with necrotising fasciitis (cases) and patients with severe cellulitis (controls) based on their ICD-9 discharge diagnosis. Controls were selected using simple random sampling. Patients with incomplete scores were excluded from this analysis. Between-group differences in demographics and outcomes were compared using independent sample t-tests and Chi-squared tests. We evaluated the discriminative ability of a positive LRINEC score (≥ 6) and SIARI score (≥ 3). The LRINEC score consists of total white cell count, hemoglobin, sodium, glucose, creatinine and C-reactive protein. The SIARI score consists of age, site of infection, presence of immunosuppresion, total white cell count, creatinine, and C-reactive protein.

Results

A total of 27 cases and 94 control patients were included in this analysis. Their baseline demographics are presented in **Table 1**, with no statistical differences between the two groups.

The Receiving Operating Characteristic (ROC) curve is shown in **Figure 1**. LRINEC had a better area under the curve (AUC) of 0.816 [95% Confidence Interval (CI): 0.737, 0.895], while SIARI had a lower AUC of 0.651 [95% CI: 0.540, 0.762].

Conclusions

In this study, the LRINEC score appears to have better a discriminative ability as compared to the SIARI score. The early diagnosis of necrotising fasciitis requires the consideration of existing risk factors, laboratory parameters and imaging results. In this study however, there was incomplete radiological data, and we were unable to draw comparisons to imaging outcomes. More robust studies are required to evaluate the performance of various measures in diagnosing necrotising fasciitis.

Table 1. Baseline characteristics

Baseline characteristics	Necrotising Fasciitis (n = 27)	Controls (n = 94)
Male, n (%)	16 (59.3)	65 (69.2)
Age in years, median (IQR)	54.0 (45.0 – 64.0)	58.0 (47.3 – 70.4)
Ethnicity, n (%)		
Chinese	13 (48.2)	53 (56.4)
Malay	11 (40.7)	27 (28.7)
Indian	2 (7.4)	13 (13.8)
Other	1 (3.7)	1 (1.1)
Medical history		
Immunosuppression, n (%)	1 (3.7)	1 (1.1)
Diabetes, n (%)	8 (29.6)	33 (35.1)
Hypertension, n (%)	12 (44.4)	47 (50.0)
Kidney failure requiring dialysis, n (%)	1 (3.7)	1 (1.1)
Ischaemic heart disease, n (%)	2 (7.4)	15 (16.0)
Chronic respiratory disease, n (%)	1 (3.7)	8 (8.5)
Chronic liver disease, n (%)	2 (7.4)	3 (3.2)
Peripheral vascular disease, n (%)	4 (14.8)	4 (4.3)

IQR: Interquartile range
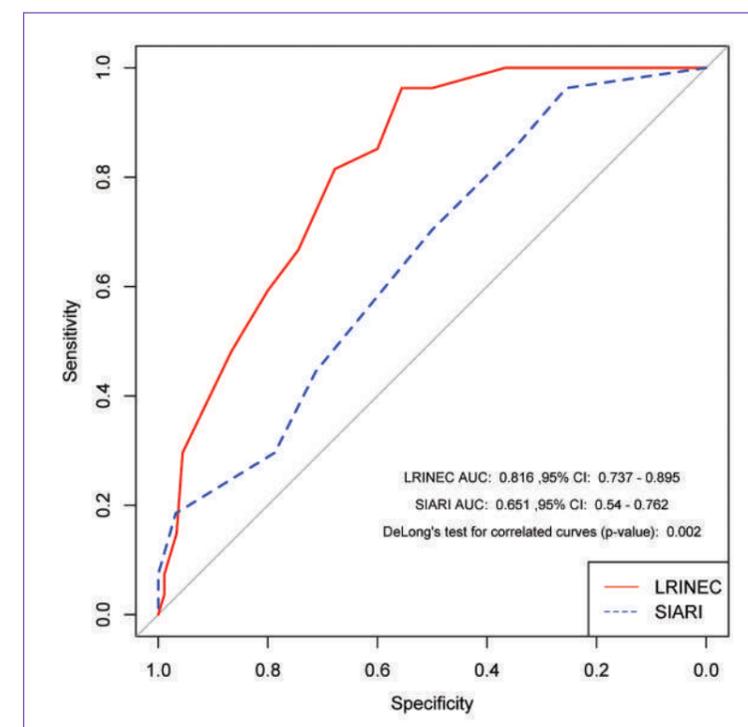
Figure 1. Receiving Operating Characteristic curves

AUC: Area under curve; CI: Confidence interval.
LRINEC: Laboratory Risk Indicator for Necrotizing Fasciitis.
SIARI: Site Other Than Lower Limb, Immunosuppression, Age, Renal Impairment, and Inflammatory Markers

LRINEC AUC: 0.816 ,95% CI: 0.737 - 0.895
SIARI AUC: 0.651 ,95% CI: 0.54 - 0.762
DeLong's test for correlated curves (p-value): 0.002
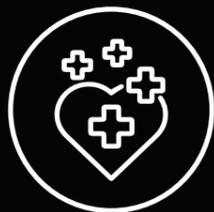
Informing Population Health Efforts

Factors influencing individuals' choice of hospitals or clinics – A cross-sectional study in northern and central Singapore

Ge Lixia, Dr Yap Chun Wei, Teow Kiok Liang

HIGHLIGHTS

- Waiting time, out-of-pocket expenses, and continuity of care were the most important factors influencing a person's choice of a hospital/clinic.
- The perceived importance of individual factors varied across demographic groups.

Introduction

Literature has shown that multiple factors contribute towards a patient's choice of a hospital or clinic. However, an individual's perception towards these factors can vary and is influenced by their preferences, conditions, needs, and values. We conducted a study to compare the potential factors influencing individuals' choice of a hospital/clinic between northern and central Singapore residents and across different demographic groups in each region.

Methods

The data on perceived importance of factors were collected using a questionnaire developed based on literature and local context. It comprised of eight factors covering distance/convenience of location, waiting time/appointment availability, out-of-pocket expenses, previous healthcare experiences, restrictions imposed by health insurers, reputation of the healthcare provider/physician, continuity of care and advertisements. Individuals were asked to indicate their perceived importance of these factors when deciding which healthcare facility to visit for medical services by choosing from the five given options: "1-Not important, "2-Less important", "3-Neutral", "4-Important", and "5-Very important". Comparisons of perceived importance between two regions and across different demographic groups were conducted for individual factors using Fisher's exact tests or Chi-squared tests.

Results

Participants who responded to the survey items in-person were included in the analysis (n=3896). The study population in the Northern region was younger than that in the Central region with 50.2% and 41.5% aged 21 to 44 years, respectively. There were 49.8% and 48.1% females in the Northern and Central regions, respectively. In addition, there were more participants who were Chinese ethnicity (77.5% vs 66.0%), staying in 1-2-room HDB flats (6.8% vs 3.9%), living alone (6.3% vs 4.1%), not employed (31.9% vs 26.8%), and having personal income ≤ S$1000 (33.9% vs 29.4%) in the Northern region compared to those in the Central region (p-value <0.05).

The top four highly important factors were "Waiting time/appointment availability" (mean: 3.36±0.74, "Very important": 50.9%), "Out-of-pocket expenses" (3.28±0.79, 47.2%), "Continuity of care" (3.21±0.73, 36.2%), and "Distance / convenience of location" (3.17±0.88, 42.4%). The least important factor was "Advertisements" (1.77±0.91, 4.6%). The same four factors had the highest mean score and the proportion of "Very important" in both regions (**Figure 1**). The distribution of importance rating for the top three factors (**Table 1**) generally varied across three age groups as well as ethnicity, and monthly personal income groups (p<0.05).

Conclusions

Waiting time, out-of-pocket expenses, and continuity of care were the most important factors influencing a person's choice of a hospital/clinic. The perceived importance varied across different demographic groups. The findings may provide insights into strategies for addressing these factors or improving patient satisfaction and the overall quality of care.

Figure 1. Comparison of proportion of "Very important" for each factor between two regions
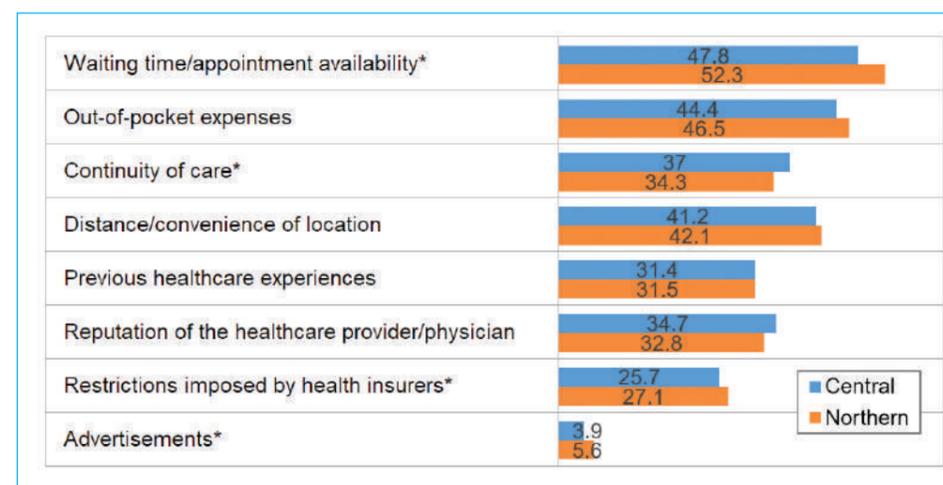
* The distribution of these factors was significantly different (p<0.05) between two regions using Fisher's Exact test.

Table 1. The comparison of the top 4 factors across demographics in each region, weighted %

Demographics	Waiting time		Out-of-pocket expenses		Continuity of care		Distance / Location	
	Central	Northern	Central	Northern	Central	Northern	Central	Northern
Age group	*0.054*	***0.005***	***0.003***	***0.010***	***0.006***	***0.049***	*0.796*	*0.220*
21 - 44 years	48.6	52.6	40.3	41.5	32.7	32.9	41.6	43.7
45 - 64 years	48.9	51.7	48.1	51.6	39.8	36.9	41.4	39.2
≥ 65 years	43.9	52.8	45.8	51.1	40.6	32.0	40.3	44.6
Ethnicity	*0.126*	*0.065*	***0.038***	*0.128*	*0.110*	***0.001***	*0.050*	*0.180*
Chinese	47.1	49.7	43.4	44.9	35.8	30.8	40.9	39.9
Malay	55.2	57.0	55.1	49.6	36.8	42.0	56.9	46.6
Indian	48.8	57.2	47.0	46.2	44.5	38.4	35.9	46.4
Others	41.6	52.3	32.7	46.5	40.4	34.3	29.5	42.1
Monthly personal income	***0.010***	*0.386*	***0.002***	*0.083*	***0.019***	*0.604*	*0.443*	***0.017***
> $4000	51.9	51.8	41.9	41.1	42.8	33.4	46.3	41.2
$1001 - $4000	50.6	53.8	46.2	47.6	34.3	34.1	38.6	39.4
≤ $1000	41.1	50.2	44.7	49.3	34.9	35.4	39.8	46.9
Housing type	*0.126*	***0.001***	***0.000***	*0.898*	*0.894*	***0.013***	*0.158*	***0.017***
1-2-room	48.2	47.7	60.4	48.7	38.4	30.2	50.3	38.3
3-4-room	49.8	50.7	45.5	46.2	37.1	32.2	41.4	43.2
5 room & above	43.0	55.4	38.1	46.7	36.5	38.2	38.8	40.5
Work status	***0.015***	***0.033***	*0.656*	*0.768*	***0.027***	*0.635*	*0.355*	*0.122*
Not employed	44.4	50.0	45.2	47.4	37.0	35.8	41.6	45.7
Employed	49.3	53.1	44.0	46.1	37.0	33.8	41.1	40.7

Maternal Health: Exploring differences in socio-economic status to identify potential care needs

Reuben Ong, Dr Ang Yee Gary

HIGHLIGHTS

- Mothers living in smaller or rental flats have been diagnosed with risk conditions (diabetes, asthma, hypertension) at a higher rate before and during pregnancy, compared to their peers.

- Mothers living in smaller or rental flats have more visits at the polyclinic and fewer to the Obstetrics or Gynaecology specialists during and after pregnancy, compared to their peers.

Introduction

Singapore has always held the health outcomes of mothers and children in high regard, exemplified by studies such as the Growing Up in Singapore Towards healthy Outcomes (GUSTO) and the Singapore PREconception Study of long-Term maternal and child Outcomes (S-PRESTO). These studies follow cohorts of mothers and their children to study their future physical and mental health outcomes, and while these studies do investigate risk factors for the general maternal population, we should also investigate subpopulations, especially groups who may have less access to healthcare. By looking at national administrative healthcare data, we may gleam differences in risk factors and health outcomes between subpopulations of mothers, and possibly identify care needs or future research areas to focus our efforts.

Methods

We explored the Population Health Staple Dataset (PHSD) and retrospectively followed mothers who delivered in 2018 at either of 3 hospitals (KK Women's and Children's Hospital, Singapore General Hospital, and National University Hospital). ICD-10-AM codes of Z37* were used to determine the hospital admission corresponding to the live delivery. Since ultrasonic examination data was not available to date the pregnancy, the antenatal period was defined as 36 weeks before delivery, and postnatal was defined as 36 weeks after delivery. Between mothers residing in smaller or rental accommodations (SRA) (rental units, studio apartments, or 1-3-room public housing flats) and those living elsewhere (4-5room or private housing), we compared the prevalence of risk factors, such as diabetes (type 1, type 2 or gestational), pre-diabetes, asthma, and hypertension in mothers during and before pregnancy, along with common complications post-delivery, and their utilisation patterns at the inpatient setting, specialist outpatient clinics (SOC), and polyclinics.

Results

A total of 17,865 mothers delivered in 2018. The ratio of SRA mothers to non-SRA mothers was 1:3 (SRA: 21.2%, non-SRA: 65.1%, missing: 13.7%). SRA mothers gave birth earlier (48.4% delivered before median age of 30 years), compared to non-SRA mothers (median age: 32 years, 31.5% delivered before age 30).

Prior to pregnancy, compared to mothers not living in SRA, disease prevalence rates of SRA mothers were higher. During the antenatal period, despite them giving birth at an earlier age on average, SRA mothers were more likely to have a first diagnosis of diabetes, asthma, and hypertension compared to non-SRA mothers (**Table 1**).

During pregnancy, SRA mothers had, on average, slightly more polyclinic visits (1.8 vs 1.2) and 1 fewer Obstetrics or Gynaecology (OBGYN) SOC visits (8.0 vs 9.1). This trend of higher number of polyclinic visits and fewer Obstetrics or Gynaecology SOC visits was consistent across trimesters. Of concern was the fact that only 57.6% of SRA mothers had a follow up with OBGYN post-delivery, compared to 77.6% of non-SRA mothers (**Table 2**). Also, a greater proportion of SRA mothers were lost to follow up after delivery (24.9% vs 13.3%).

Table 1. Risk factors and complications in mothers studied

Period	Condition	Non-SRA mothers (n=11,628)	SRA mothers (n=3,786)	Odds ratio (unadjusted)
Prenatal (<36 weeks prior to delivery)	Diabetes (Type 1 & 2)	121 (1.0%)	59 (1.6%)	1.50
	Pre-Diabetes	42 (0.4%)	18 (0.5%)	1.32
	Asthma	835 (7.2%)	502 (13.3%)	1.86
	Hypertension	150 (1.3%)	69 (1.8%)	1.41
Antenatal (within 36 weeks prior to delivery)	Diabetes (Type 1 & 2)	16 (0.1%)	9 (0.2%)	1.73
	Asthma	34 (0.3%)	24 (0.6%)	2.17
	Hypertension	23 (0.2%)	11 (0.3%)	1.47
	Pregnancy Hypertension	98 (0.8%)	35 (0.9%)	1.10
Post-delivery	Pyrexia	157 (1.4%)	49 (1.3%)	0.96
	Eclampsia and pre-eclampsia	247 (2.1%)	88 (2.3%)	1.10
	Mental and behavioral disorders	14 (0.1%)	1 (0.0%)	0.22
	Anxiety and panic disorder	9 (0.1%)	4 (0.1%)	1.37
	Depressive episode	28 (0.2%)	11 (0.3%)	1.21

SRA: living in smaller or rental accommodations

Table 2. Healthcare utilisation of mothers studied

	Non-SRA Mothers (n=11,628)	SRA mothers (n=3,786)	Non-SRA Mothers (n=11,628)	SRA mothers (n=3,786)
	Before delivery		**After delivery**	
With OBGYN SOC visits	5,142 (44.2%)	884 (23.3%)	6,050 (52.0%)	1,186 (31.3%)
With both OBGYN & polyclinic visits	6,300 (54.2%)	2,836 (74.9%)	2,975 (25.6%)	995 (26.3%)
With polyclinic visits only	34 (0.3%)	28 (0.7%)	1,055 (9.1%)	658 (17.4%)

OBGYN: Obstetrics or Gynaecology; SRA: living in smaller or rental accommodations; SOC: Specialist outpatient clinic

Conclusions

While useful to survey the maternal sub-population, the database also poses limitations such as the inability to discern first births from subsequent ones, or to clearly pick out pregnancy-related polyclinic visits. Some mothers were also lost to follow up and may have transitioned to the private healthcare sector. More studies are needed to uncover why SRA mothers are presenting a higher rate of certain pregnancy risk conditions, and primary surveys are needed to understand the healthcare utilisation preference differences between groups.

Landscape study on the healthcare utilisation of chronic obstructive pulmonary disease by smoking status

Dr Aidan Lyanzhiang Tan

HIGHLIGHTS

- Post-diagnosis of COPD, healthcare service utilisation generally increases, especially for outpatient services (specialist outpatient clinic, polyclinic).
- Smoking status does not appear to significantly impact utilisation pre/post diagnosis.

Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic condition that may cause high burden to the health system. A landscape study describing the healthcare service utilisation prior to, and post diagnosis of COPD was conducted to evaluate utilisation patterns and to identify any differences between smoking status (current/ex-smokers vs non-smokers).

Methods

A retrospective descriptive study was conducted on patients diagnosed with COPD between 2018 to 2021. Utilisation data was drawn from National Healthcare Group (NHG) institutions, including Tan Tock Seng Hospital, Khoo Teck Puat Hospital, Institute of Mental Health, National Centre for Infectious Diseases and National Healthcare Group Polyclinics (Geylang, Kallang and Queenstown polyclinics were included). Utilisation patterns were tracked 360 days before and after the COPD diagnosis date. Healthcare services measured included visits to day-surgery, Emergency Department (ED), polyclinic, and Specialist Outpatient Clinic (SOC), as well as days spent in hospital. Pre and post comparisons were conducted between 360-days pre- and post-COPD diagnosis, with a tail-180 days pre- and post-comparison done to exclude the immediate surge utilisation post diagnosis.

Results

A total of 4,967 COPD patients were included, with 3,562 (72%) being current/ex-smokers. Majority were diagnosed at the ED or inpatient setting. Current/ex-smokers tended to be younger, more male and of non-Chinese ethnicity (**Table 1**). Non-smokers tended to be older, of Chinese ethnicity and female.

A comparison of utilisation (360-days pre/post) is described in **Table 2**. Among current/ex-smokers, there was an increase in day-surgery, polyclinic, and SOC visits post-diagnosis, while emergency visits and days spent hospitalised decreased. Non-smokers similarly showed an increase in day-surgery and SOC visits, while ED, polyclinic visits, and days spent hospitalised decreased. When comparing tail-180 days trends, there appeared to be a general increase in utilisation across all services for both groups, as shown in **Table 3**.

Conclusions

Majority of the COPD patients were current/ex-smokers. For both current/ex-smokers and non-smokers, healthcare service utilisation generally appeared to increase post-diagnosis across majority of the services. Such an increase is not entirely unexpected, given the need for follow-up and treatment at polyclinics or SOC. Utilisation reduction efforts for one service may result in increased utilisation for other services.

Table 1. Demographics by cohorts and smoking status

Year of diagnosis	2018		2019		2020		2021	
Smoking status	Current /Ex	Non	Current /Ex	Non	Current /Ex	Non	Current /Ex	Non
Age (mean, SD)	68.9 (12.6)	71 (15.2)	68.3 (11.9)	69.4 (14.4)	68.9 (12.6)	70.6 (13.6)	68.4 (11.9)	70.2 (14.4)
Female (n, %)	121 (12%)	187 (52%)	80 (9%)	204 (55%)	61 (8%)	162 (52%)	69 (8%)	186 (52%)
Chinese (n, %)	715 (70%)	274 (76%)	621 (70%)	294 (79%)	517 (69%)	237 (76%)	651 (71%)	279 (78%)

SD: Standard deviation

Table 2. Absolute and relative change in healthcare service utilisation 360 days pre- and post-diagnosis (average per patient per month)

Year of diagnosis		2018		2019		2020		2021	
Current/ Ex-smokers	DS	0.004	24%	0.003	19%	0.002	16%	0.003	14%
	EMD	-0.04	-25%	-0.04	-25%	-0.03	-28%	-0.03	-28%
	Poly	0.03	8%	0.01	2%	-0.01	-2%	-0.01	-3%
	SOC	0.23	58%	0.16	37%	0.18	38%	0.16	36%
	Hosp	-0.36	-32%	-0.25	-25%	-0.27	-24%	-0.29	-27%
Non-smokers	DS	0.01	45%	-0.007	-29%	0.001	3%	0.01	43%
	EMD	-0.04	-33%	-0.06	-39%	-0.05	-42%	-0.04	-42%
	Poly	-0.004	-1%	-0.08	-19%	0.04	12%	-0.01	-2%
	SOC	0.18	32%	0.1	16%	0.14	29%	0.18	36%
	Hosp	-0.23	-23%	-0.31	-31%	0.1	11%	-0.36	-33%

DS: Day surgery; ED: Emergency Department visits; Hosp: Days spent hospitalised; Poly: Polyclinic; SOC: Specialist Outpatient Clinic

Table 3. Absolute and relative change in healthcare service utilisation tail-180 days pre- and post-diagnosis (average per patient per month)

Year of diagnosis		2018		2019		2020		2021	
Current/ Ex-smokers	DS	0.002	16%	0.002	11%	0.002	9%	0.01	26%
	EMD	0.02	26%	0.01	5%	-0.03	39%	0.04	35%
	Poly	0.02	6%	-0.003	-1%	-0.01	-5%	-0.03	-4%
	SOC	0.19	53%	0.1	27%	0.18	30%	0.28	38%
	Hosp	0.07	14%	0.1	25%	-0.27	39%	0.51	72%
Non-smokers	DS	0.01	40%	-0.02	-43%	0.001	4%	0.02	100%
	EMD	0.01	16%	-0.01	-16%	0.02	32%	0.005	4%
	Poly	0.01	1%	-0.11	-28%	-0.01	-3%	-0.07	-10%
	SOC	0.13	27%	0.03	5%	0.1	21%	0.26	31%
	Hosp	0.2	56%	0.19	55%	0.54	228%	0.52	69%

DS: Day surgery; ED: Emergency Department visits; Hosp: Days spent hospitalised; Poly: Polyclinic; SOC: Specialist Outpatient Clinic

Estimating the impact of reduced smoking prevalence on deaths averted from smoking-related causes

*Dr Joseph Antonio D. Molina, Teow Kiok Liang, Palvannan R. K., Dr Ang Yee Gary, Dr John Abisheganaden*

HIGHLIGHT

- Over the last 15 years, Singapore has implemented numerous population-wide anti-smoking initiatives, with smoking prevalence for the same period showing a steady decline. Reducing smoking prevalence may potentially avert hundreds of deaths from various causes every year.

Introduction

Of the various risk factors for disease, tobacco use contributes the second highest Disability Adjusted Life Years in Singapore. From 2007 to 2021, at least 20 anti-smoking initiatives involving a combination of tobacco taxation, legislation, public education, partnerships with various stakeholders, and smoking cessation services were implemented (**Figure 1**). This study aimed to estimate the number of deaths averted from specific causes, due to the (education in smoking prevalence between 2007 and 2021.

Figure 1. Smoking prevalence (%) and various anti-smoking initiatives implemented in Singapore, 2007 to 2021
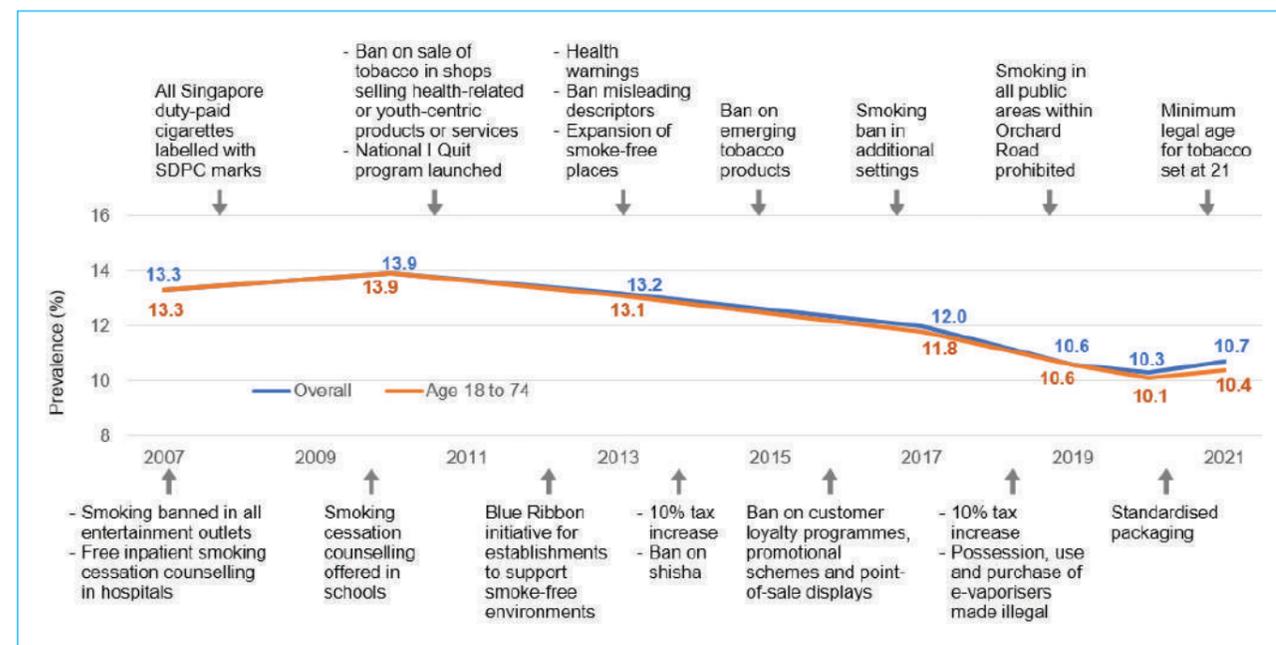
Methods

The number of deaths averted due to reduction in smoking prevalence for all causes, lung cancer, chronic obstructive pulmonary disease (COPD), ischaemic heart disease (IHD), and stroke was estimated using the following equation:

| Cause-specific mortality risk difference between smokers and non-smokers	$*$	Difference in the number of smokers between baseline (year 2007) and follow-up (year 2021)

Mortality rates among smokers and non-smokers for the various causes were based on data from the Singapore Chinese Health Study.[1] The number of smokers was based on (a) age-standardised smoking prevalence,[2] and (b) the population of Singapore residents aged 18 to 74,[3] for years 2007 and 2021. The age group of 18 to 74 years was chosen for this study as it encompassed the age range at highest risk of smoking and who are amenable to smoking cessation interventions.

Results

The annual absolute all-cause mortality rate from various causes for smokers and non-smokers is presented in **Figure 2**. In relative terms, mortality rates were higher for smokers than non-smokers by 61.9%, 88.0%, 95.2%, 55.1%, and 29.4%, for all-causes, lung cancer, COPD, IHD and stroke, respectively. From 2007 to 2021, the age-standardised smoking prevalence for Singapore residents decreased steadily from 13.3% to 10.7% (**Figure 1**). Factoring in the change in the size of the Singapore resident population, 600 deaths from all causes were averted per year. Of the four smoking-related diseases in the study, the highest number of deaths was averted from lung cancer, followed by IHD, COPD, and stroke (**Table 1**). Had smoking been completely eliminated during the same period, it was estimated that the number of deaths averted could have been 4 to 5 times higher than what was observed.
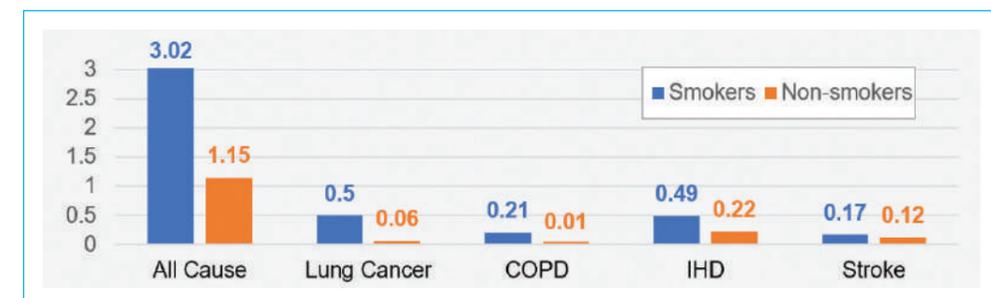
Figure 2. Mortality rates (%) for current smokers vs. non-smokers*

*Based on Lim SH, et. al. Smoking cessation and mortality among middle-aged and elderly Chinese in Singapore: the Singapore Chinese Health Study.

Table 1. Cause-specific number of deaths averted per year due to reduction in smoking prevalence between 2007 and 2021

	All cause	Lung cancer	COPD	IHD	Stroke
No. of deaths averted per year due to reduction in smoking prevalence	600	142	62	85	20
No. of deaths averted per year for every 1% reduction in smoking prevalence	207	49	21	29	7
Deaths averted per year if smoking prevalence is reduced to 0	2,754	652	283	391	93

COPD: chronic obstructive pulmonary disease; IHD: ischaemic heart disease

Conclusions

A sustained, multi-pronged, population-wide anti-smoking strategy may prevent hundreds of deaths from various causes annually. The impact may ripple beyond health outcomes, with a reduction in DALYs potentially leading to greater productivity and economic benefits.

References
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Impact of the COVID-19 pandemic on Emergency Department attendances and hospitalisation for asthma and chronic obstructive pulmonary diseases in Singapore

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HIGHLIGHT

- A notable decrease in Emergency Department visits and admissions for obstructive airway diseases was observed during the COVID-19 pandemic, without significant change in overall mortality and duration of hospital stay.

Introduction

The prolonged impact of the COVID-19 pandemic on non-COVID respiratory diseases remains uncertain. The objective of this study was to determine its impact on asthma and chronic obstructive pulmonary diseases (COPD) Emergency Department (ED) attendances and hospital admissions, compared to pre-pandemic utilisation trends.

Methods

This study identified all ED attendances and admissions with a discharge diagnosis of acute asthma or COPD exacerbation between 1st January 2015 and 31st December 2022 to the National Healthcare Group's hospitals from a central cluster electronic record database. Rates of ED attendances, admissions and all-cause mortality in these patients pre- and post-pandemic were compared.

Results

For asthma, the median number of all-cause ED visits per 10,000 patients reduced from 92.6 per week (2015-2019) to 58.6 per week (2020-2021), (**Figure 1**, $p<0.001$). This remained sustained in 2022 (65.1 ED visits per 10,000, $p<0.001$).

For COPD, the median number of all-cause ED visits per 10,000 patients fell from 204.5 per week (2015-2019) to 137.2 per week (2020-2021, $p<0.001$), and persisted in 2022 (151.0 ED visits per week, $p<0.001$). These occurred without increases in mortality or average length of hospital stay over the three-year period. With the end of the pandemic, the utilisation trends for ED visits and hospitalisations returned to pre-pandemic levels (**Figure 2**).

Conclusions

There was a notable decrease in ED visits and admissions for obstructive airway diseases during the COVID-19 pandemic without significant change in overall mortality and duration of hospital stay. Our study highlighted the potential of telemedicine and home monitoring to reduce unnecessary ED attendances and hospital admissions in the future.
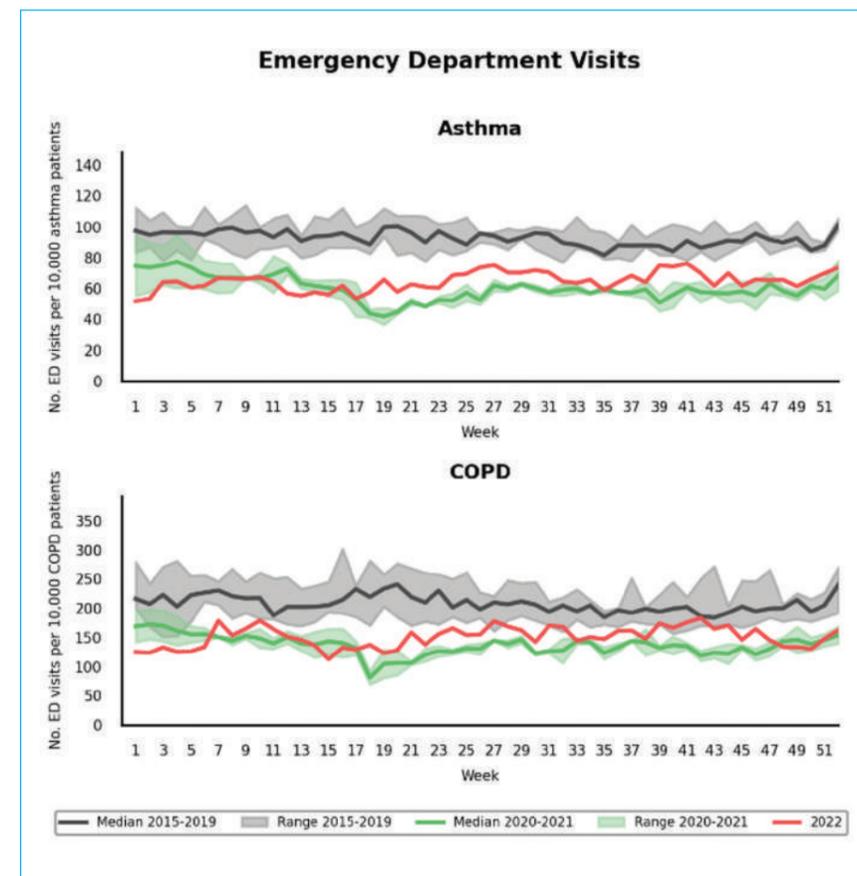
Figure 1. Number of all-cause ED visits among asthma and COPD patients
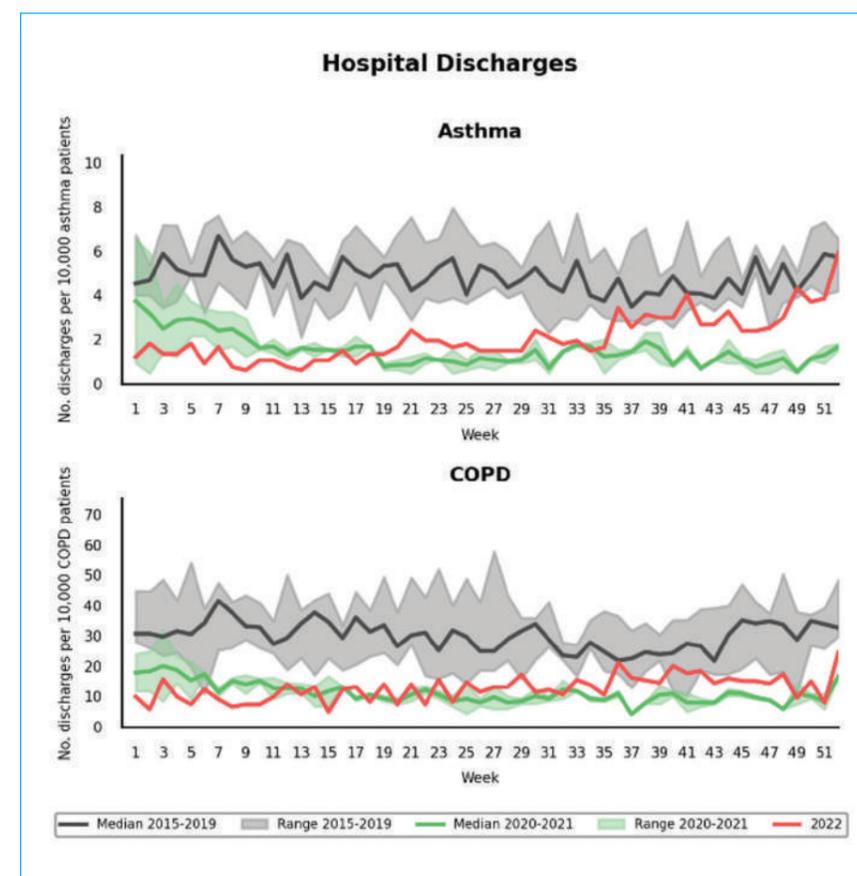
Figure 2. Number of discharges among asthma and COPD patients

Demand projection of obstructive sleep apnea and projected number of sleep physicians in Singapore from 2025 to 2035

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HIGHLIGHTS

- Projected number of adults aged 20-79 with moderate to severe OSA in 2035 was about 338,000 in the Central and North region and 883,000 in Singapore.

- The projected number of sleep physicians is highly dependent on diagnosis rates and partial FTEs. Assuming a 100% diagnosis rate, the total FTEs of sleep physicians was estimated to be 65.

Introduction

Obstructive sleep apnea (OSA) is a disorder characterized by repetitive complete or partial collapse of the upper airway during sleep. It is a common problematic disorder associated with substantial morbidity and economic cost. Untreated OSA is associated with increased cardiovascular and cerebrovascular morbidity, daytime sleepiness, accidents, poorer neurocognitive function and work performance, healthcare expenditures, and reduced quality of life. In Singapore, while the prevalence of OSA is high, the current diagnosis and treatment rates are very low. This study aims to (1) project demand (aged 20-79) of moderate to severe OSA in the National Healthcare Group (NHG) cluster in Singapore; (2) to forecast the total full-time equivalents (FTEs) and the number of sleep physicians on a national level in Singapore with the anticipated increase in OSA diagnoses.

Methods

Age-specific prevalence of moderate to severe OSA (33% for aged 20-59, 14% for aged 60-79) with an overall prevalence of about 27% from a published Singapore study was used to project OSA demand in NHG, based on the projected resident population from 2025 to 2035 in the central and northern region of Singapore. "What if" analysis was conducted to project the OSA burden under different scenarios of diagnosis rates and treatment rates. Similarly, OSA demand in Singapore was projected based on the projected national resident population. The total FTEs was assessed using OSA demand and patient-to-sleep physician ratio (15800:1.16) in Seoul, which was estimated based on published South Korea studies. The number of sleep physicians was then projected based on different diagnosis rates and partial FTEs of sleep physicians.

Results

The number of adults aged 20-79 with moderate to severe OSA was projected to be 338,136, 340,054 and 337,421 in the NHG region in 2025, 2030 and 2035, respectively. From the "What if" analysis (**Table 1**), in the case of 10% diagnosis rate with 30% treatment rate, the respective projected number of patients would be 10,144, 10,202, and 10,123. A 5 percent increase in diagnosis rate (i.e., 15% diagnosis rate) with 30% treatment rate would greatly increase the OSA burden to 15,216, 15,302, and 15,184. We observed that with increasing diagnosis and/or treatment rates, OSA burden increased. At the national level, adults aged 20-79 with moderate to severe OSA was projected to be 883,051, 887,223 and 883,054 in 2025, 2030 and 2035, respectively. The corresponding projected total FTEs was 64.8, 65.1 and 64.8, respectively, assuming a 100% diagnosis rate. Furthermore, as shown in **Table 2**, the number of projected sleep physicians decreased with lower diagnosis rates.

Table 1. Projected adults with moderate to severe OSA in NHG region assuming different diagnosis rates and treatment rates

Diagnosis rate	Treatment rate	2025	2030	2035
15%	50%	15,216	15,302	15,184
	30%	25,360	25,504	25,307
	100%	50,720	51,008	50,613
20%	30%	20,288	20,403	20,245
	50%	33,814	34,005	33,742
	100%	67,627	68,011	67,484
25%	30%	25,360	25,504	25,307
	50%	42,267	42,507	42,178
	100%	84,534	85,014	84,355

Table 2. Projected sleep physicians in Singapore given different diagnosis rates and FTEs

| Diagnosis rate | FTE | Number of sleep physicians | | |
		2025	2030	2035
20%	0.5	26	27	26
	0.7	19	19	19
	0.8	17	17	17
	0.9	15	15	15
40%	0.5	52	53	52
	0.7	38	38	38
	0.8	33	33	33
	0.9	29	29	29
60%	0.5	78	79	78
	0.7	56	56	56
	0.8	49	49	49
	0.9	44	44	44
80%	0.5	**104**	105	104
	0.7	**75**	75	75
	0.8	**65**	66	65
	0.9	**58**	58	58

FTE: full-time equivalents

Conclusions

Due to lack of local patient data on sleep disorders, our analysis and the derived results were limited. Diagnosis rates appear to have a high impact on capacity projection of sleep physicians. The obtained results could be useful to decision makers in capacity planning of new sleep services to meet the OSA burden in the future.

Quality of care for acute myocardial infarction and congestive heart failure using Organisation for Economic Co-operation and Development Healthcare Quality Outcomes

Dr Aidan Lyanzhiang Tan, Palvannan R.K.

HIGHLIGHTS

- Care quality for cardiac conditions can be measured using Organisation for Economic Co-operation and Development indicators.

- As differences in performance may be due to population differences amongst other factors, risk-adjustment is important for comparisons between institutions.

Introduction

Cardiac conditions, such as acute myocardial infarction (AMI) and congestive heart failure (CHF), are important conditions that entail significant morbidity and mortality in Singapore. As such, they have been included in the Organisation for Economic Co-operation and Development (OECD) healthcare quality outcomes. The National Healthcare Group (NHG) Heart Institute recently requested a review of NHG patients with these conditions based on the OECD indicators.

Methods

We collected deidentified retrospective data from Tan Tock Seng Hospital and Khoo Teck Puat Hospital patients admitted for AMI or CHF between 2017 and 2021 using the Population Health Data Mart. Presence of AMI and CHF were identified based on ICD-10 diagnosis codes.

Quality of care for these patients was measured using OECD indicators for integration of care, comprising 365-day readmissions (all-cause and condition-specific), all-cause 365-day mortality post-discharge, and case fatality within 30 days of admission. As these indicators were only for CHF patients, the definitions were adapted for AMI. Acute care for AMI was measured via 30-day mortality rate. Denominator for this indicator included: (1) unique patients presenting with AMI, and (2) admissions for AMI.

Results

There were differences between institutions as shown in **Figures 1 and 2**. When adjusted for age, comorbidity and gender, or age, comorbidity and ethnicity, these differences between institutions were not fully accounted for.

Conclusions

Care quality for cardiac conditions can be measured using metrics such as OECD indicators. These may be benchmarked against national data from the Ministry of Health. However, there may be differences in performance which may arise from population differences, such as differing demographics and socioeconomic statuses, amongst other factors such as health care facility availability and accessibility. Risk-adjustment should be considered for more fair comparisons.

Figure 1. OECD indicators for integration of care for acute myocardial infarction and congestive heart failure across 2017-2021
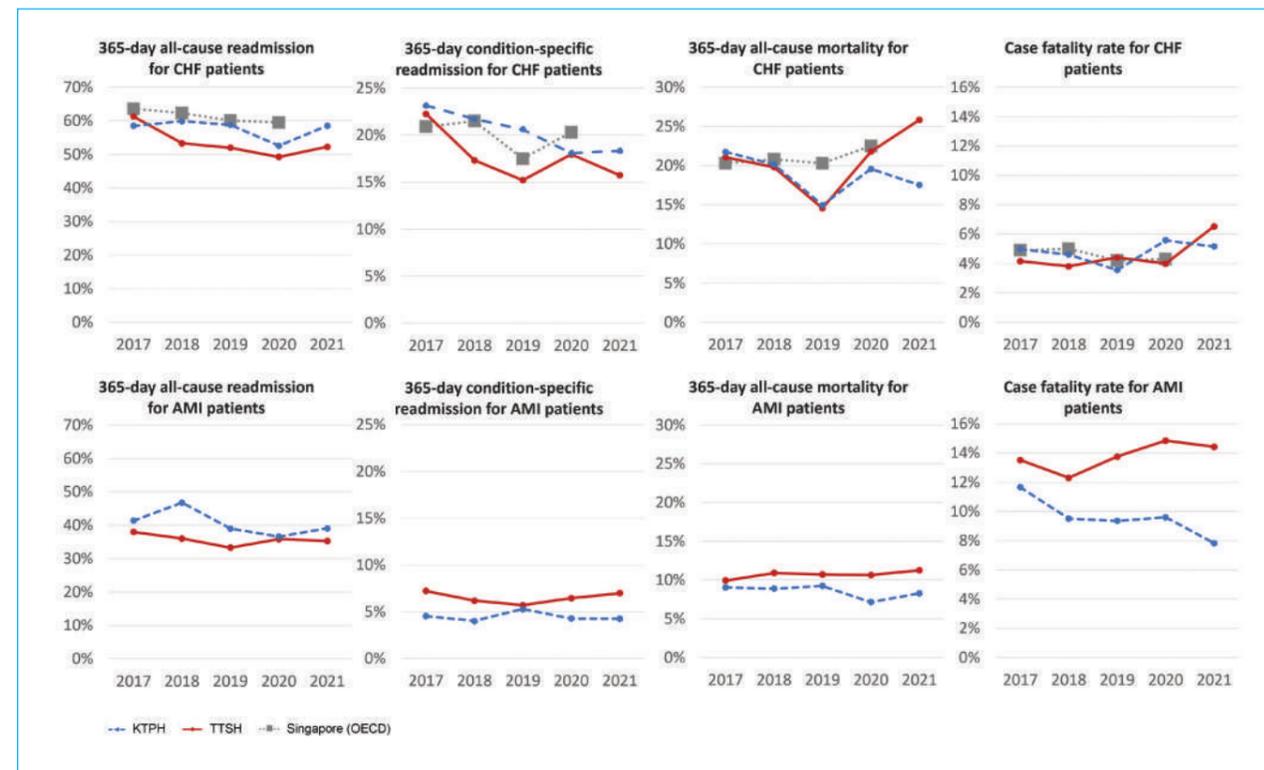
AMI: acute myocardial infarction; CHF: congestive heart failure; KTPH: Khoo Teck Puat Hospital; TTSH: Tan Tock Seng Hospital

Figure 2. OECD acute care indicators for acute myocardial infarction across 2017-2021
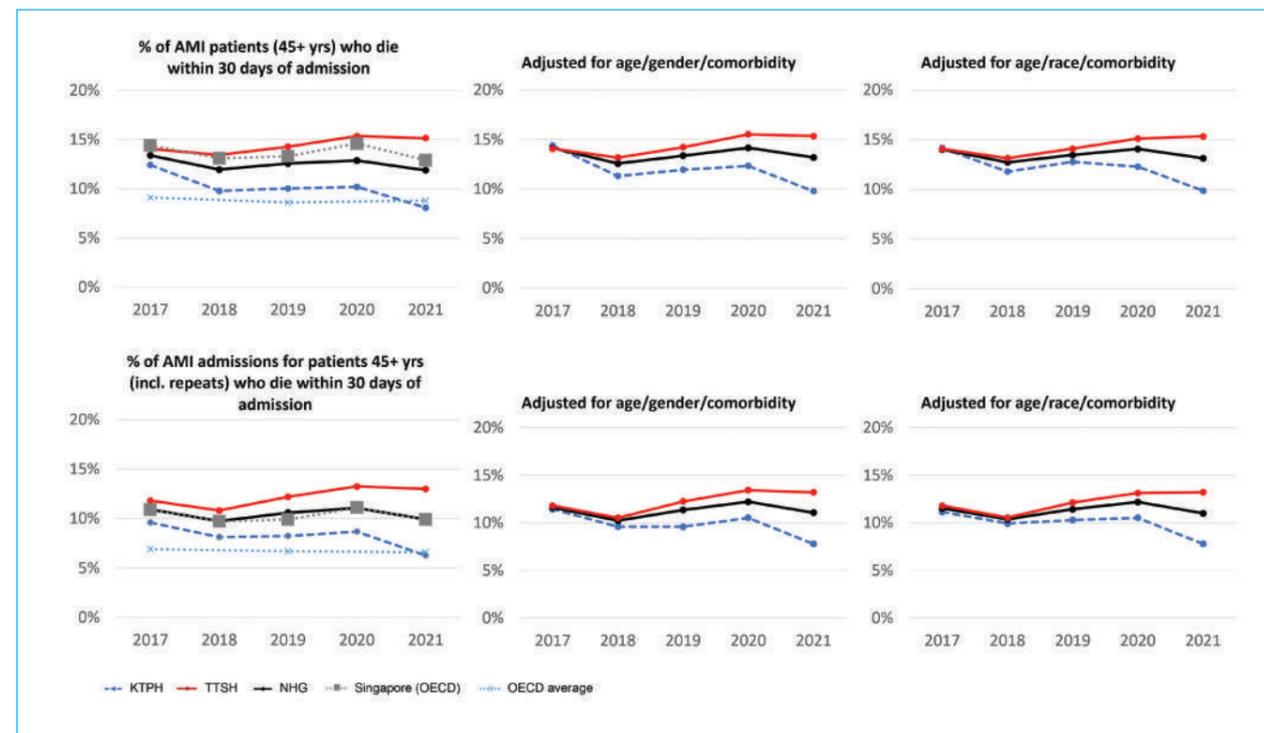
AMI: acute myocardial infarction; KTPH: Khoo Teck Puat Hospital; TTSH: Tan Tock Seng Hospital

Evaluation of Program Implementation and Outcomes

Stroke Life Support Central Health Alliance, Registry and Technology Enabled care (SLS CHARTER): An interim analysis of process indicators, patient-reported outcomes, and healthcare utilisation

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HIGHLIGHTS

- Most of programme patients (86%) had used a post-stroke checklist in the six-months post stroke, and on average, the checklist was utilised thrice.
- Almost a fifth of programme patients had raised post-stroke issues with care coordinators, but most of these issues were resolved.

Introduction

The Stroke Life Support Central Health Alliance, Registry and Technology Enabled care (SLS CHARTER) sited at Tan Tock Seng Hospital facilitates the provision of timely and seamless care to stroke patients through several key features:

- Empowerment of patients and caregivers on the usage of post-stroke checklist (PSC)
- Coordination of care by CHASE coordinators within the CHASE network of stroke care providers

Programme patients were educated on the use of PSC, which was self-administered within 6-months post-stroke. They were encouraged to raise their post-stroke related issues (if they answered "Yes" for any item(s) on the checklist) with their care coordinators. In this preliminary analysis, we aimed to describe the programme patients, the care coordination received from CHASE, and patient-reported outcomes.

Methods

Patients admitted to the Acute Stroke Unit between January and June 2023 with a diagnosis of either an ischemic or haemorrhagic stroke were recruited to the study. We summarised patients' demographics and call log patterns. Other patient outcomes were only described for patients who had completed their 6-month follow-up. This comprised of self-reported PSC usage, mean scores of Stroke Impact Scale (SIS) aggregated over 59 items, proportion of and days taken to return-to-work from index admission date, length of stay (LOS), emergency department (ED) visits, and hospital re-admissions.

Results

Of the 250 patients, 164 (65.6%) were male, 202 (80.8%) were of Chinese ethnicity, with a mean age of 63.1 years. The majority (80.4%) had an ischemic stroke, with a mean National Institutes of Health Stroke Scale score of 6.5 (Standard Deviation (SD): 6.7) and a mean Modified Barthel Index score of 58.1 (SD: 29.6).

Fifty programme patients (20.0%) completed 6-months follow-up, and most (86.0%) had self-administered the PSC at least once, with a median usage of 3 times (Interquartile range: 1-9). Their mean SIS score was 82.4 (SD: 13.7). Forty-five patients (18.0%) raised stroke-related issues with the coordinators using the PSC. More than half (n = 26) were repeat callers who made more than one call. The most common reasons for calls were related to patients experiencing other challenges, secondary prevention, and return-to-work (**Figure 1**). Other challenges faced by patients were largely related to the community care plan, medical issues, and outpatient appointments (**Figure 2**). Most issues were resolved by the coordinators with a case completion rate of 97.5%. The most common actions taken by the coordinators were the coordination of care with partners (49.0%), appointment expedition, creation, or actualisation (24.0%), and patient education (24.0%).

Figure 1. Reasons for calls captured in the post-stroke checklist
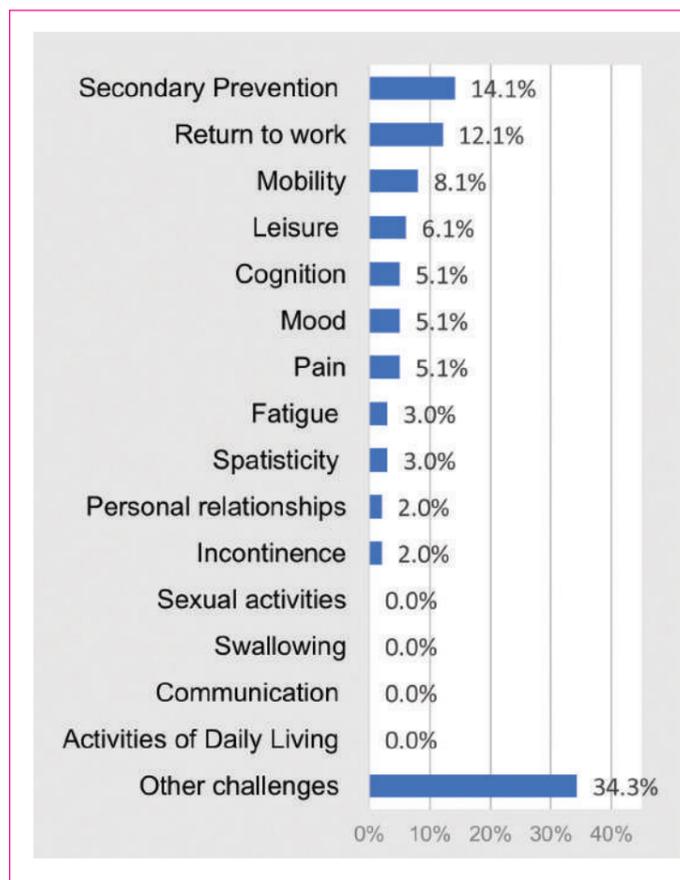
Figure 2. Other reasons for calls
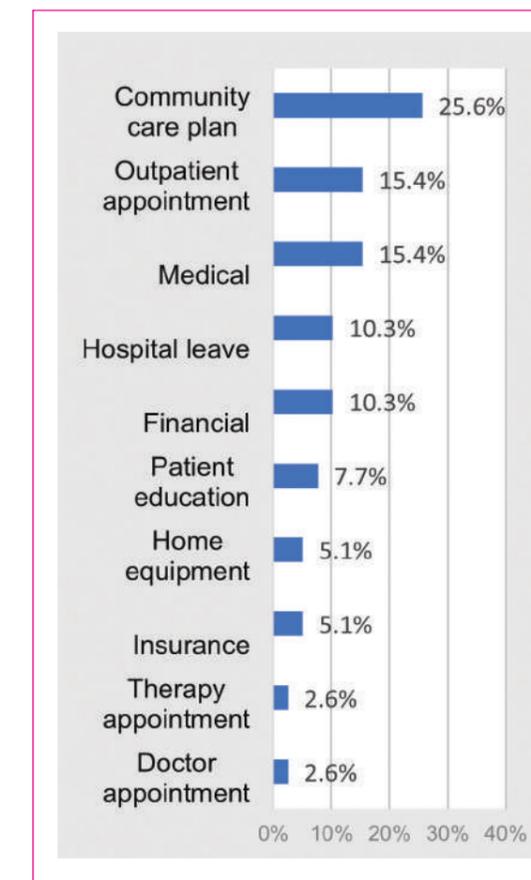
Of the 26 patients employed at baseline, slightly more than half (57.7%) returned to work within 6 months post-stroke. On average, they took 91.7 days (SD: 54.0) to return to work. For acute healthcare utilisation, 12.0% had ED visits and 20.0% had re-admissions, with a mean LOS of 1.2 days (SD: 8.2).

Conclusions

In this interim analysis, stroke patients utilised the PSC and tapped on the care coordinators for post-stroke related issues. Both PSC and care coordinators have the potential to facilitate the early identification of post-stroke issues and right-siting of care. A final evaluation will be conducted through a prospective comparison of the SLS CHARTER patients to a control group.

Evaluation of a multi-component intervention to implement Advance Care Planning in nursing homes

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HIGHLIGHTS

- Project RESPECT improved the capability and confidence of nursing home staff in facilitating advance care planning discussions for residents and their families, and introduced workflows for the initiation, completion and documentation of these discussions.

- More institution- and system-level support to integrate advance care planning into routine care and practice is required for its sustainability in nursing homes.

Introduction

Project Respecting Preferences, Empowering Conversations Together (RESPECT) aims to support nursing homes (NHs) in the Central Health region to provide Advance Care Planning (ACP) for their residents. Components of the program included (1) setting up workflows and systems conducive to the facilitation of ACP within the NHs, (2) conducting ACP facilitator trainings and subsequent mentorship for NH staff, as well as (3) raising awareness and publicity for ACP among non-clinical staff and residents' next-of-kin (NOK). Hence, a multi-methods approach was adopted to evaluate the implementation process and impacts of Project RESPECT, and we report interim findings for a two-year period up to September 2023.

Training and mentoring of ACP facilitators

The RESPECT team conducted a total of 30 trainings on facilitating either General ACP (GACP) discussions for residents with stable disease, or Preferred Plan of Care (PPC) discussions for residents with life-limiting illnesses. Of the 87 trained facilitators, 38 went on to be mentored by the RESPECT team in actual ACP discussions, while 7 progressed to facilitate discussions independently.

To assess whether the program improved the capability and confidence of NH staff in facilitating ACP discussions, we surveyed participants on their knowledge, attitudes and confidence towards facilitating ACP before the one-day training begun and at three months later. Questionnaires used were adapted from studies on equipping healthcare professionals with ACP facilitation skills. The 51 participants on average answered more knowledge-based questions correctly at follow-up than baseline, but this change was not statistically significant. Most participants also reported an increase in agreement towards the importance, responsibilities, and need for ACP advocacy in the NH, and an increase in confidence in their ACP facilitation skills.

Implementation of ACP in the NH

We adopted a qualitative approach in exploring the challenges encountered by the NH staff in implementing ACP, and to understand the role of Project RESPECT in this process. Our findings demonstrate that, despite the unquestionable intrinsic benefit of ACP, NH staff usually do not think that the current approach integrates effectively into an environment with limited staffing and significant turnover. ACP operational outcomes, such as initiation and completion of discussions, have also been erratic because of workflow issues and last-minute

modifications to hospitalisation decisions by the NOK. Collectively, these lead to challenges in actualising elicited ACP preferences. While the concept of ACP is sound, the efforts to involve NOKs in ACP discussions might not be worthwhile due to the considerable number of last-minute changes in decisions. Although standardized workflows have been implemented, there have not been adequate efforts to foster support for ACP. NHs will need to collaborate closely with their staff to jointly rethink job roles and reach a consensus on them to better integrate ACP into usual practice. To initiate change at the sectoral level, ACP may need to be explicitly acknowledged as a crucial part of care in nursing homes.

Uptake of ACP and patient-reported outcomes

A total of 31 GACPs and 115 PPCs were completed over the two-year period. For residents with cognitive impairment, their NOK participated in the ACP discussion on their behalf. To assess the impact of ACP on residents and their NOKs, we surveyed participants before starting the discussion and at three months later. They were asked about their sentiments on decisional conflict towards end-of-life (EOL) care options for themselves or their loved ones, as well as their readiness and confidence to engage in ACP activities, such as talking to doctors and family members about their care preferences and formalising these decisions. The Decisional Conflict Scale and the ACP Engagement Survey (AES) were used respectively.[1,2] The AES was additionally modified for NOKs to survey them on their own propensity for ACP.

We found that decisional conflict scores reduced over the three-month period in the 37 NOKs surveyed, with the greatest change in feeling more informed about their decisions. However, this change was not observed in the nine residents. There was also no statistically significant improvement in readiness and self-efficacy for ACP among all participants. Examining trends from baseline to three months, residents were slightly more ready and confident to talk to their doctors about their care, but the inclinations were less consistent for the behaviours of approaching, talking to and appointing a proxy. In contrast, NOKs appeared more ready and confident to sign off on their family member's EOL plans, and to discuss their own care preferences with a potential proxy, but not in formalising their own ACPs.

Conclusions

Project RESPECT improved the capability and confidence of NH staff in ACP facilitation and enabled them to translate the training into their work. The team also introduced systematic workflows and a general awareness of ACP to encourage and guide its practice within the NH. While Project RESPECT has indeed supported NHs in various components of practising ACP, establishment of a sustainable culture is limited by manpower constraints persistent in the NH setting. Addressing systemic barriers such as protecting time for ACP and mitigating turnover of trained staff must be done alongside initiatives such as Project RESPECT to ensure sustained change within the institution.

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Survival and healthcare utilisation outcomes of Home Ventilation and Respiratory Support Service (HVRSS) patients: A retrospective case-control study

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HIGHLIGHT

- Home ventilation support has the potential to allow ventilator-assisted individuals to spend more days outside hospital and reduce acute healthcare utilisation.

Introduction

The multi-disciplinary Home Ventilation and Respiratory Support Service (HVRSS) provides home care services to patients with chronic ventilatory failure. We aimed to evaluate the differences in survival and healthcare utilisation outcomes between deceased ventilator-assisted individuals with and without HVRSS follow-up.

Methods

A retrospective case-control study was conducted using patients' episodic data extracted from administrative and HVRSS databases. Patients were enrolled into HVRSS if they had hypercapnic respiratory failure or progressive neuromuscular disease with respiratory or sleep-related symptoms. Control patients were selected for the analysis if they had similar clinical trajectories. Furthermore, these patients must have had at least two inpatient episodes within the three years prior to death fulfilling the following criteria: 1) HVRSS-relevant disease diagnoses were recorded; 2) multiple admissions to Tan Tock Seng Hospital were with ventilator use; and 3) a critical ward stay of one day or more was recorded. Both HVRSS and control patients deceased as of December 2019 were included in the analysis.

We conducted survival analyses using the log-rank test and Cox proportional hazards model, with the latter adjusted for demographics, comorbidities, primary diagnosis, and ventilation type. Additionally, we derived the proportion of hospital-free days over the enrolment period and evaluated between-group differences using multivariable linear regression. For adjusted analyses of healthcare utilisation up to 6 months prior to death, only HVRSS patients enrolled in the service for at least 6 months were compared with the control group. Negative binomial models were used to compare length of stay (LOS), and the number of admissions and outpatient visits between groups. Generalised linear models (Gamma family, Log link) were used to model healthcare costs. Socio-demographics, comorbidities, primary diagnosis, and ventilation type were adjusted for in all aforementioned models.

Results

A total of 57 HVRSS patients and 106 control patients were included in this analysis. Their baseline demographics are presented in **Table 1**. From the survival analyses, there was no significant difference between groups, as the log-rank test reported a p-value of 0.585, and the hazard ratio was 0.876 [95% Confidence Interval (CI): 0.53-1.49] in the Cox proportional hazards model.

The median enrolment time was 392 days (interquartile range (IQR): 107 – 1020 days) and 498.5 days (IQR: 143 – 972 days) for HVRSS and control patients respectively. The median hospital-free days were 392 days (IQR: 60 – 1014 days) and 423 days (IQR: 122 – 874 days) for the HVRSS and control patients respectively. The adjusted proportion of hospital-free days were 91.8% and 77.3% respectively, with the HVRSS patients spending more days (14.5% higher [95% CI: 4.44-26.64]) outside of the hospital.

Of the 57 HVRSS patients, 38 (66.7%) had been enrolled for at least 6 months. In the adjusted healthcare utilisation analysis (**Table 2**), HVRSS patients enrolled 6 months or longer were more likely to have reduced number of admissions and length of stay, and were more likely to incur lower inpatient costs and overall healthcare costs compared to the controls.

Table 1. Baseline demographics

Baseline demographics	HVRSS (n = 57)	Control (n = 106)	P-value
Male, n (%)	38 (66.7%)	52 (49.1%)	0.031[a]
Age at enrolment, years (SD)	62.7 (19.1)	71.3 (12.4)	<0.001[b]
Age at death, years (SD)	64.5 (18.9)	73.0 (12.3)	<0.001[b]
Invasive ventilation1, n (%)	30 (52.6%)	8 (7.5%)	<0.001[a]
Primary diagnosis, n (%)			
Chronic Respiratory Disease	6 (10.5%)	61 (57.6%)	
Motor Neuron Disease	15 (26.3%)	0 (0.0%)	
Neuromuscular Disease	8 (14.0%)	9 (8.5%)	<0.001[a]
Obesity Hypoventilation Syndrome	2 (3.5%)	18 (17.0%)	
Spinal Cord Injury	13 (22.8%)	0 (0.0%)	
Others	13 (22.8%)	18 (17.0%)	

HVRSS: Home Ventilation and Respiratory Support Service; SD: Standard deviation; [a] Chi-squared test; [b] Independent sample t-test;
[1] Invasive (tracheostomy) versus non-invasive (via natural airways)

Table 2. Healthcare utilisation 6-months prior to death, by study group

Measure, mean (IQR)	HVRSS enrolled ≥6 months (n = 38)	Controls (n = 106)	IRR (95% CI)	P-value
Number of admissions	1 (0 – 1)	2 (1 – 3)	0.32 (0.21, 0.49)	<0.001*
Length of stay	3 (0 – 14)	35.5 (11 – 68)	0.08 (0.04, 0.17)	<0.001*
Number of SOC visits	8 (5 – 16)	5 (2 – 10)	0.89 (0.59, 1.34)	0.577
Inpatient costs	$2,891 ($0 – $22,395)	$42,009 ($11,950 – $71,228)	0.05 (0.02, 0.14)	<0.001*
Outpatient costs	$1,794 ($974 – $3,127)	$838 ($212 – $1,678)	1.12 (0.53, 2.38)	0.769
Overall healthcare costs	**$5,384 ($1,997 – $24,811)**	**$45,183 ($13,256–$72,285)**	**0.07 (0.04, 0.14)**	**<0.001***

* P-value < 0.05; IRR: incidence rate ratio; IQR: Interquartile range; SOC: Specialist outpatient clinic

Conclusions

HVRSS is a service which shifts ventilation provision and care to home for ventilator-dependent individuals who require long-term ventilation. Despite similar survival between-groups, the HVRSS has the potential to allow patients to spend more survival days outside the hospital and reduce acute healthcare utilisation.

Integrated Management and Palliative Care for Terminally ill Non-cancer Patients (IMPACT): Results from a retrospective study of death and healthcare utilisation outcomes

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HIGHLIGHT

- A dedicated, specialist-led palliative homecare programme for end-stage organ failure may improve home death rates, and reduce healthcare utilisation and costs.

Introduction

Programme IMPACT (PI) aims to improve the quality of life of terminally ill non-cancer patients, reduce unnecessary admissions to acute hospital, and enhance capabilities of community health partners to provide home palliative care services for non-complex patients. Among a cohort of deceased end-stage organ failure (ESOF) patients, we aimed to compare home death and acute healthcare utilisation outcomes between those without palliative homecare support (CG1, reference group), and i. those who received PI (PI versus CG1); and ii. those who received palliative homecare from a community service provider (CG2) [CG2 versus CG1].

Methods

A retrospective cohort study from Quarter 4, 2017 to 2020 was performed. To assemble a control group, deaths recorded in the national death registry during the study period were first screened. The following criteria was then used to identify potential control patients: i. All-cause TTSH admissions in the last year of life: ≥2 for heart failure and respiratory failure, ≥1 for renal failure; and ii. A principal, final or secondary ESOF diagnosis in the final year of life. Any decedent with cancer as a cause of death or co-morbidity, or received renal replacement therapy, or utilised inpatient hospice services in the last year of life were excluded. Additionally, control patients who crossed over to the intervention arm were assigned as PI patients.

Place of death, cumulative inpatient (IP) admissions, length of stay (LOS), emergency department (ED) and specialist outpatient clinic (SOC) visits, associated costs and total costs during the last 6-, 3-, and 1-month of life, were extracted and compared between groups. Logistic regressions were used to examine home death rates. Different cumulative healthcare utilisation types were examined using Poisson regression models. Healthcare costs were considered using Generalised Linear Models (Gamma family, Log link). p-values <0.05 were deemed significant. All multivariate (MV) statistical models were adjusted for ESOF type, gender, race, death age, death year, and housing type.

Results

A total of 148 PI, 853 CG1 and 83 CG2 decedent patients were analysed (**Table 1**). PI patients were enrolled for 93.3 days (SD=108.0) on average before their demise. Percentage of home deaths across groups (and sub-groups) can be found in **Figure 1**. Most PI patients passed away at their own residence (63.5%). Majority of control patients died in a public hospital (CG1=82.9%; CG2=57.8%). Through multivariate adjustment, we found that PI patients were 16.6 times more likely to pass away at home (95%CI): 10.2-27.0). Results from our MV healthcare utilisation analyses are depicted in **Figure 2**. PI patients incurred less IP admissions, IP costs, LOS, and total costs at all look-back periods [Incidence rate ratios (IRRs): 0.65-0.85; all p<0.05], compared to CG1 patients. PI patients incurred less ED visits and costs at all look-back periods (IRRs: 0.69-0.81; all p<0.05), but only at 3- and 6-mo look-back periods for SOC visits (IRRs: 0.80-0.86; all p<0.05), compared to CG1 patients. For CG2 patients, they incurred more IP LOS at 6-months (IRRs=1.06; all p=0.005), but less IP and total costs at 1- and 3-mo look-back periods

(IRRs: 0.73-0.82; all p<0.05), compared to CG1 patients. No differences in ED and SOC visits (and associated costs) at all look-back periods were found for CG2 compared to CG1 patients.

**Table 1. Breakdown of patient numbers**

Groups	PI	CG1	CG2
Overall, n (%)	148 (100%)	853 (100%)	83 (100%)
HF, n (%)	38 (25.7%)	554 (64.9%)	33 (39.8%)
RespF, n (%)	26 (17.6%)	177 (20.8%)	23 (27.7%)
RF, n (%)	84 (56.8%)	122 (14.3%)	27 (32.5%)

CG1: Control group1; CG2: Control group 2; HF: Heart failure;
RespF: Respiratory failure; RF: Renal failure; PI: Programme Impact

Figure 1. Home death percentages
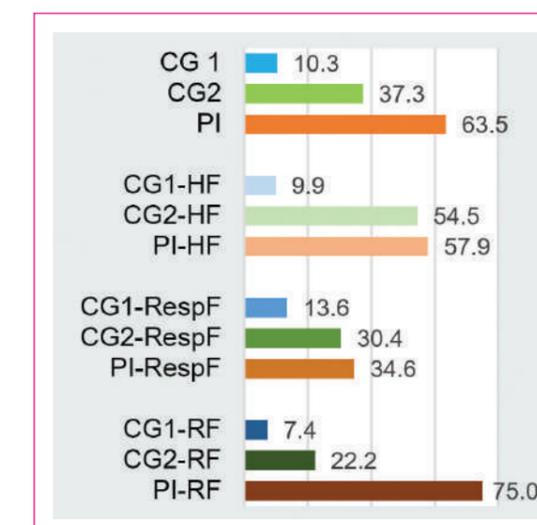
Figure 2. Results of multivariate healthcare utilisation analyses (Incidence rate ratios and 95% confidence intervals shown)
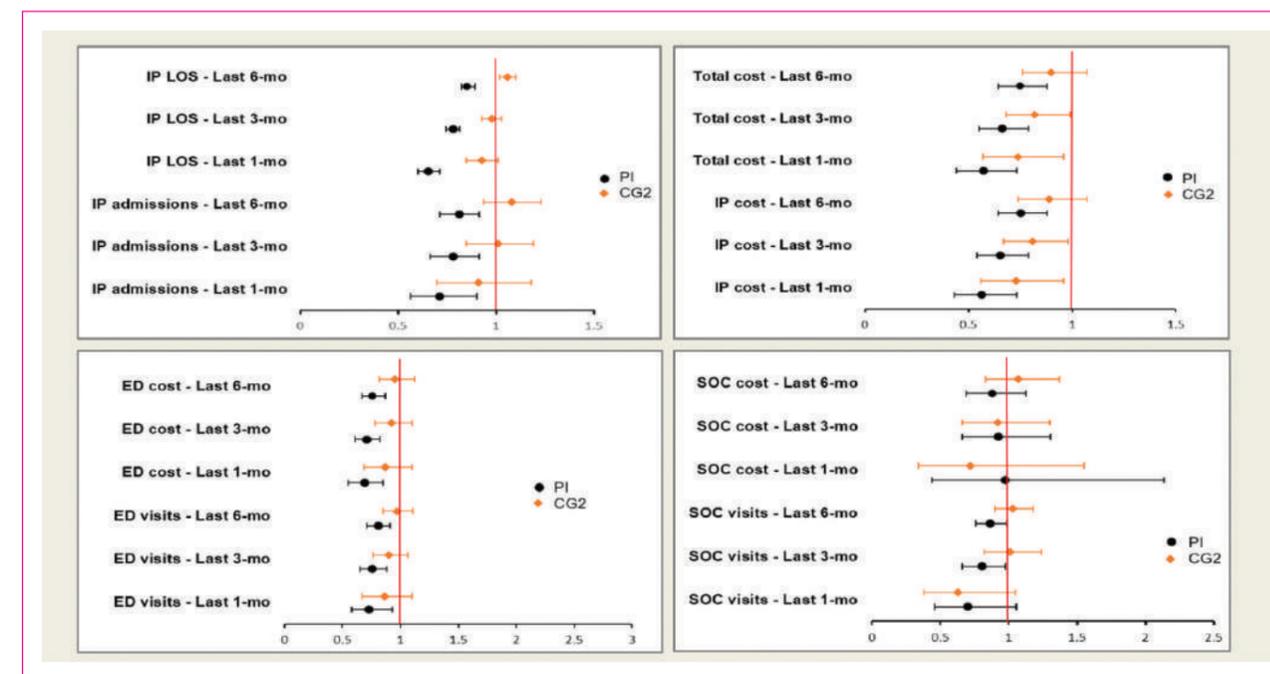
Conclusions

We found that Programme IMPACT, a dedicated, specialist-led palliative homecare programme for ESOF patients, may improve rates of home deaths and reduce healthcare utilisation and costs, when compared to those without such support, and to a greater extent than community service palliative homecare providers in some instances. Following the folding of programme funding in March 2022, Programme IMPACT's model of care has been successfully integrated into Dover Park Hospice's homecare service as IMPACT@DPH.

Integrated Management and Palliative Care for Terminally ill Non-cancer Patients (IMPACT): A prospective analysis on achieving good palliative outcomes and honouring patients' preferences

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HIGHLIGHTS

- On average, 60% of patients who experienced an exacerbation of symptoms saw an improvement of 2.5 Edmonton Symptom Assessment Scale points by the subsequent visit.
- ≥90% patients had their end-of-life care preferences honoured.

Introduction

Program IMPACT (PI) aims to establish effectiveness in providing palliative care for terminally ill non-cancer patients, in terms of achieving good palliative outcomes, and honouring patients' preferences for place of death.

Methods

A single-arm prospective study design was employed. Patients who were enrolled into PI during 2nd October 2017 and 10th December 2021 were included in the analysis. To assess for palliative outcomes, the Edmonton Symptom Assessment Scale (ESAS), a numeric rating scale (0: best; 10 worst), was used to assess for 10 common symptoms experienced by end-of-life (EoL) patients. The symptoms assessed were anxiety, appetite, confusion, depression, drowsiness, dyspnea, nausea, pain, tiredness, and well-being. Based on clinical inputs, symptoms such as constipation, itch, and lower limb oedema were also assessed. A change in ESAS scores after an exacerbation, defined as ESAS≥4, was the primary outcome tracked. In addition, we computed concordance achieved between patients' EoL care preferences and actualised outcomes. We included preferences documented in both formal and informal advance care plans.

Results

A total of 387 unique patients with a mean age of 82.3 (standard deviation, SD: 9.8) years, who were largely male (56%) and of Chinese ethnicity (88%), were included in the analysis. Majority of the referrals to PI came from the inpatient setting (70%) and patients were enrolled in PI for 5.1 months (SD: 6.1 months). On average, 68.8% of patients saw an improvement of at least 2.5 ESAS points across all 13 symptoms (**Figure 1**).

Of these patients, 281 died during this period, with a mean time to death from enrolment of 3.5 months. About 95% of decedents had either formal (n=165) or informal (n=102) documentation of advanced care plans (**Figure 2**). High concordance was achieved for preferences regarding cardiopulmonary resuscitation (94.8%), medical interventions (96.3%), and place of death (89.1%). The key reasons for not achieving concordance included deviations from the documented decision by family members during time of crisis, as well as a lack of awareness of patients' preferences by paramedics/hospital staff.

Figure 1. ESAS scores during exacerbation (Mod-High ESAS score) and the subsequent ESAS score

Symptoms	n	Mod-High ESAS score		Next ESAS Score		Δ Scores (95 % CI)	% Change		
		Mean	SD	Mean	SD		↓	-	↑
Constipation	390	6.7	1.3	4.1	3.1	**2.5** (95% CI: 2.2 to 2.8)	6.2	37.7	56.2
Appetite	280	6.7	1.4	4.6	3.2	**2.1** (95% CI: 1.8 to 2.5)	7.9	42.9	49.3
Dyspnoea	229	6.1	0.9	3.0	2.4	**3.1** (95% CI: 2.8 to 3.4)	2.2	21.4	76.4
Tiredness	227	6.3	1.0	4.0	2.9	**2.3** (95% CI: 1.9 to 2.7)	6.2	37.0	56.8
Lower limb odema	204	6.2	1.1	4.4	2.8	**1.8** (95% CI:1.5 to 2.2)	6.9	43.6	49.5
Drowsiness	189	6.8	1.4	5.0	3.3	**1.8** (95% CI:1.4 to 2.2)	7.9	47.1	45.0
Well-being	141	6.3	1.1	3.0	2.7	**3.3** (95% CI:2.8 to 3.8)	3.5	25.5	70.9
Confusion	94	6.5	1.1	4.7	2.6	**1.8** (95% CI: 1.3 to 2.3)	3.2	53.2	43.6
Pain	76	6.2	1.0	2.6	2.9	**3.6** (95% CI: 2.9 to 4.2)	5.3	11.8	82.9
Itch	64	6.4	1.3	3.3	2.6	**3.0** (95% CI:2.3 to 3.7)	6.3	21.9	71.9
Depression	38	6.2	1.0	3.8	2.6	**2.4** (95% CI:1.6 to 3.3)	5.3	31.6	63.2
Anxiety	35	6.3	1.5	3.3	2.6	**3.0** (95% CI: 2.1 to 3.8)	0.0	25.7	74.3
Nausea	20	6.2	0.7	1.1	1.8	**5.1** (95% CI: 4.7 to 6.1)	0.0	5.0	95.0

ESAS: Edmonton Symptom Assessment Scale; CI: confidence interval; SD: standard deviation

Figure 2. Concordance between patients' preferences and actualised outcomes
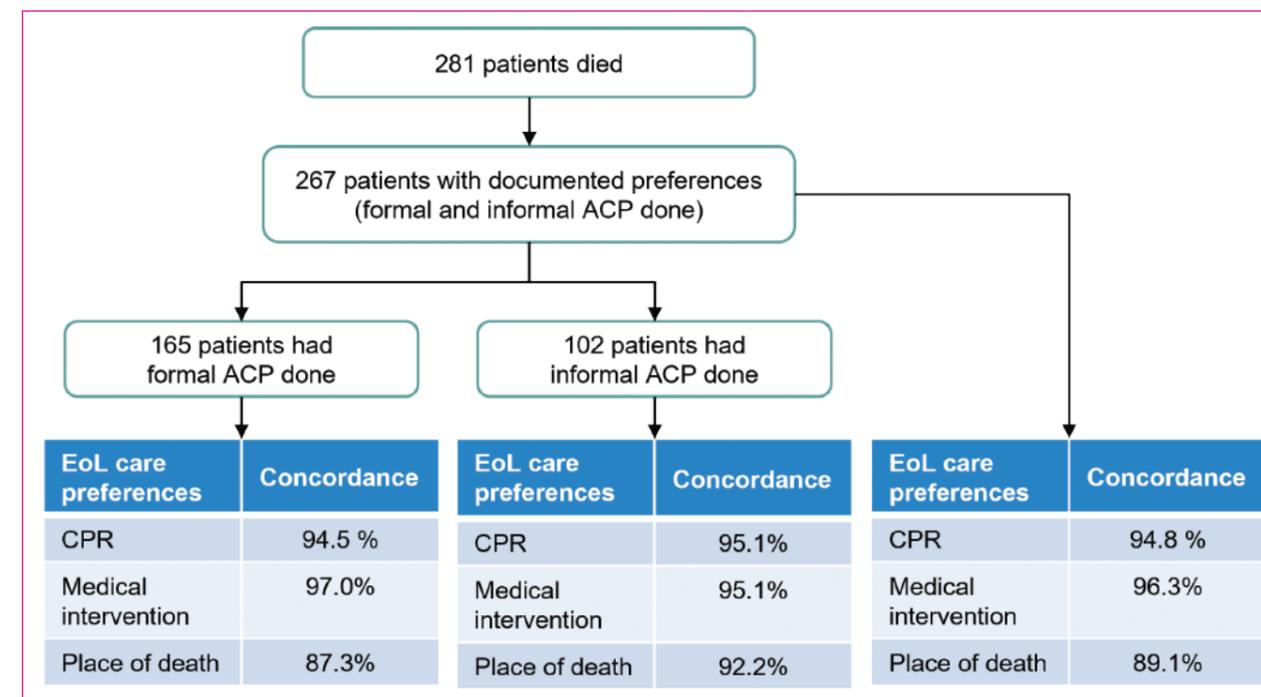
ACP: advance care plan; CPR: cardio-pulmonary resuscitation; EoL: end-of-life

Conclusions

PI has shown to achieve good palliative outcomes and honouring patients' preference for EoL care. However, concordance can be further improved by exploring system-level access to EoL care preferences.

Healthcare Financing and Economic Evaluation

Impact analysis of a new hospital on market share redistribution

Dr Zhu Zhecheng

HIGHLIGHT

- This study proposes a method to estimate market share redistribution to assist future capacity planning in the event of a new hospital establishment.

Introduction

When a new hospital is established, the market share of existing hospitals will be redistributed. For stakeholders overseeing hospital capacity planning, it is important to know how the addition of a hospital affects the existing market share. This study presents a method to estimate market share redistribution in a steady state.

Methods

The market share of hospital A in a specific area B is determined by several factors:

- Travelling time from area B to hospital A: market share of A increases with shorter travelling time.
- If hospital A is the nearest hospital to area B, market share of A increases.
- If hospital A and area B are situated in the same cluster, market share of A increases.

The steps of estimating market share redistribution is listed as below:

1. Select a reference year, e.g., 2017, the year before Sengkang General Hospital (SKH).
2. Compute market share of each existing hospital by subzone.
3. Generate market share lookup table for existing hospitals.
4. Construct market share lookup table for new hospital.
5. Normalize market share redistribution at each subzone.
6. Aggregate redistributed market share by different resolutions.
7. Validate the estimated market share if actual value available.
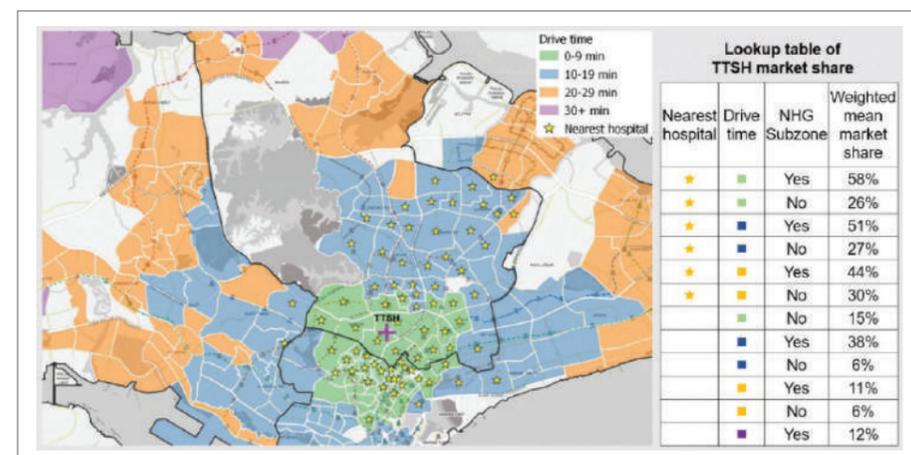
Figure 1. Market share of Tan Tock Seng Hospital by subzones, 2017

Figure 1 illustrates the market share of Tan Tock Seng Hospital (TTSH) in 2017, before the opening of SKH. A lookup table is constructed to stratify the market share of TTSH in all subzones by several factors: nearest hospital (yes or no), drive time (four categories), and whether they belong to same cluster (yes or no). There are 12 possible market share values, and each subzone can belong to any one of the market share values depending on the aforementioned factors.
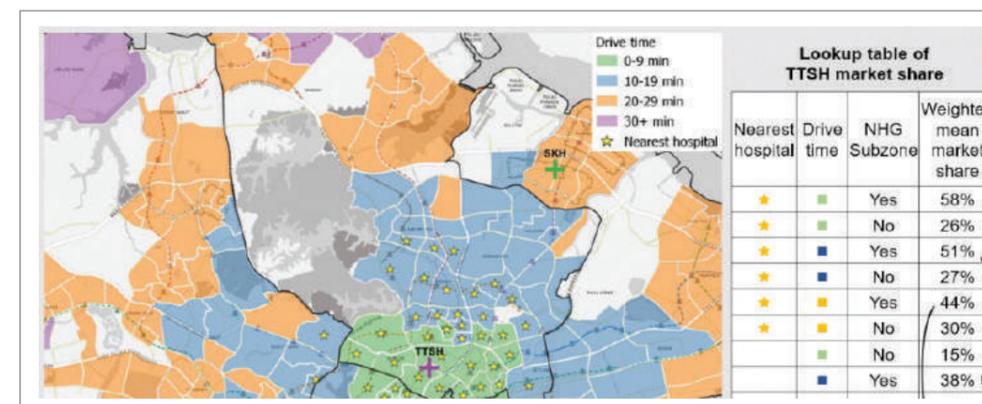
Figure 2. SKH impact on TTSH market share

Figure 2 illustrates the impact of SKH on TTSH market share. In subzones near SKH, we observed that TTSH is no longer the nearest hospital. Thus we see a reduction in market share in those subzones.
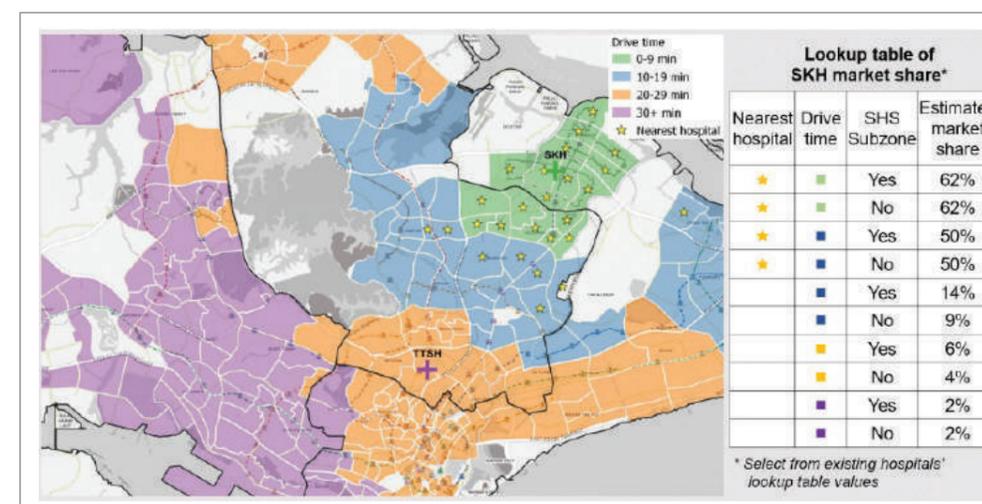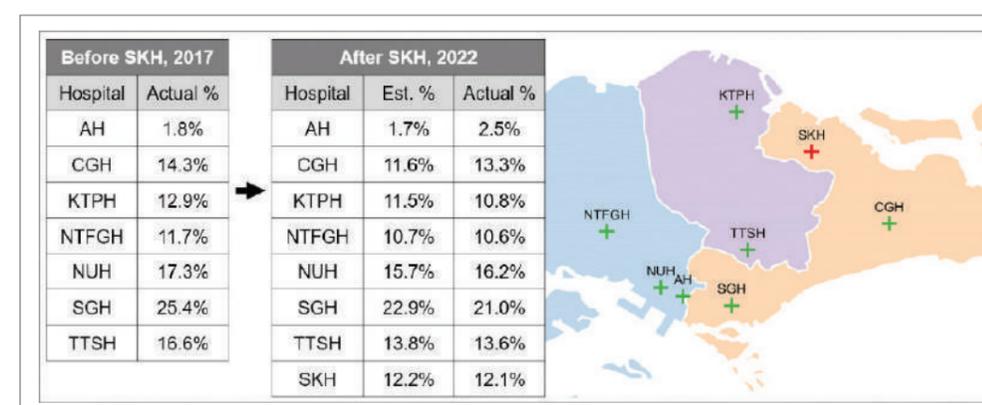

Figure 3. Estimation of SKH market share by subzones

Figure 3 illustrates the estimation of SKH market share by subzones. There are 10 estimated market share values. Each value is estimated based on the market share of other existing hospitals that share similar factors.

Results

Figure 4 illustrates the impact of SKH on market share redistribution. The estimated market share of SKH in 2022 is 12.2%, which is close to the actual value (12.1%). TTSH's market share dropped from 16.6% in 2017 to 13.8% (estimated) in 2022. However, the method overestimates Singapore General Hospital's market share and underestimates Changi General Hospital's market share.

Figure 4. Impact of SKH on market share redistribution

Before SKH, 2017		After SKH, 2022		
Hospital	Actual %	Hospital	Est. %	Actual %
AH	1.8%	AH	1.7%	2.5%
CGH	14.3%	CGH	11.6%	13.3%
KTPH	12.9%	KTPH	11.5%	10.8%
NTFGH	11.7%	NTFGH	10.7%	10.6%
NUH	17.3%	NUH	15.7%	16.2%
SGH	25.4%	SGH	22.9%	21.0%
TTSH	16.6%	TTSH	13.8%	13.6%
		SKH	12.2%	12.1%

Conclusions

This study has presented a method to estimate market share redistribution. It may assist stakeholders' capacity planning.

Cost-effectiveness analysis of obstructive sleep apnea diagnosis and treatment with continuous positive airway pressure in Singapore

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HIGHLIGHT

- From a health system perspective, the estimated treatment cost for patients with obstructive sleep apnea under an inpatient sleep study was $25,008 per DALY averted, which can be reduced by 29.3% through the alternative home-based sleep test.

Introduction

Obstructive sleep apnea (OSA) is a disorder characterized by repetitive complete or partial collapse of the upper airway during sleep. Untreated OSA is associated with increased cardiovascular and cerebrovascular morbidity, daytime sleepiness, accidents, healthcare expenditures, poorer neurocognitive function and work performance and reduced quality of life. Continuous positive airway pressure (CPAP) is the first line treatment for OSA and has been proven to improve the aforementioned outcomes. Treatment efficacy is however limited by varying adherence. While the assessment of cost-effectiveness of CPAP therapy is important to public health decision-making, there is a scarcity of publications in Singapore. This study aims to determine the cost-effectiveness of OSA diagnosis and treatment with CPAP from a health system perspective, thus enabling health policy makers to better plan for effective diagnosis and management strategies.

Methods

Cost-effectiveness of OSA diagnosis and treatment with CPAP was analysed by comparing the costs and outcomes between patients with and without treatment.1 Diagnosis was made either by inpatient sleep study or home-based sleep test (HST). Markov modelling was used to assess cost-effectiveness in a 5-year treatment pathway with weighted adherence rate of 74.1% and discount rate of 3% (**Figure 1**), considering health system cost savings of OSA and OSA-related comorbidities, direct costs of diagnosis and CPAP treatment, and incremental benefit of quality of life measured using Disability Adjusted Life Years (DALYs). The incremental cost-effectiveness ratio (ICER) was then estimated, with a weighted CPAP adherence from two local Singapore studies and direct costs from Tan Tock Seng Hospital's sleep lab. Efficacy of CPAP treatment, health system costs and DALYs were obtained from published literature. Sensitivity analysis was conducted using Monte Carlo simulation on major parameters used in the Markov model, each following PERT distribution. A one-way sensitivity analysis was undertaken by changing base value of each major parameter by 15%, keeping other parameters unchanged.

Results

As shown in **Table 1**, the estimated cost of CPAP treatment of patients diagnosed with OSA who undergone an inpatient sleep study was $25,008 per DALY averted. For patients who underwent a home-based sleep test, the ICER achieved a 29.3% reduction, specifically $17,691 per DALY averted.

Conclusions

CPAP was found to be cost effective compared to no treatment in the management of moderate to severe OSA. The obtained results may be helpful to policy makers in decision making related to funding OSA diagnosis and CPAP treatment in the local health system.

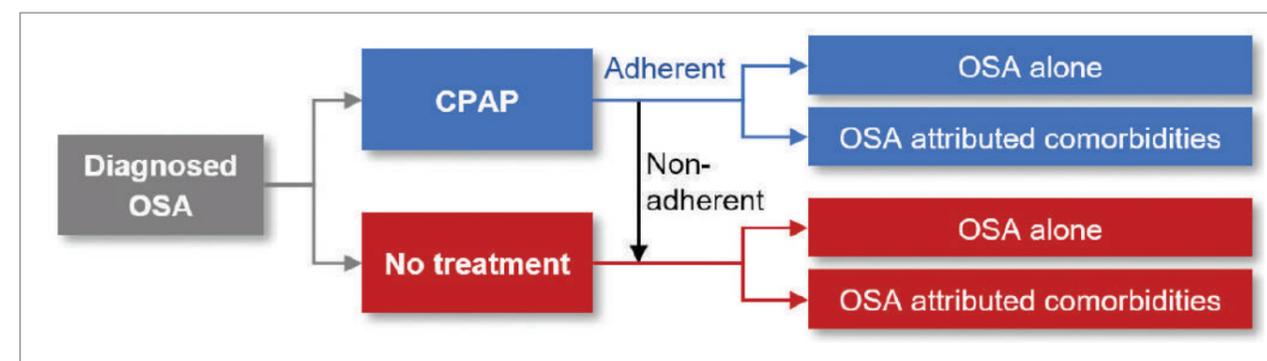**Figure 1. Markov model of patients with CPAP treatment and with no treatment**

Table 1. Cost-effectiveness analysis of diagnosis and treatment with CPAP

Item	Weighted adherence of 74.1%	
	HST	Inpatient sleep study
Cost of diagnosis and treatment per case ($)	813	1,117
Health system cost savings per case ($)	77	77
Net cost per case ($)	736	1,040
DALYs averted per case	0.0416	0.0416
ICER ($ per DALY per case)	17,691	25,008
ICER reduction compared to inpatient sleep study	29.3%	

HST: Home-based sleep test; DALYs: Disability adjusted life years; ICER: Incremental cost effectiveness ratio

Figure 2 shows the results of the one-way sensitivity analysis for diagnosis with inpatient sleep study, which indicate that direct costs, effectiveness of CPAP treatment, and adherence had higher impact on the cost-effectiveness of CPAP therapy. Specifically, greater improvement on ICER was achieved with a 15% reduction in direct costs of diagnosis and treatment, or a 15% increase in effectiveness of CPAP treatment, or a 15% increase in adherence. Similar trends were observed for patients who underwent the home-based sleep test.

Figure 2. Tornado diagram of one-way sensitivity analysis – inpatient sleep study
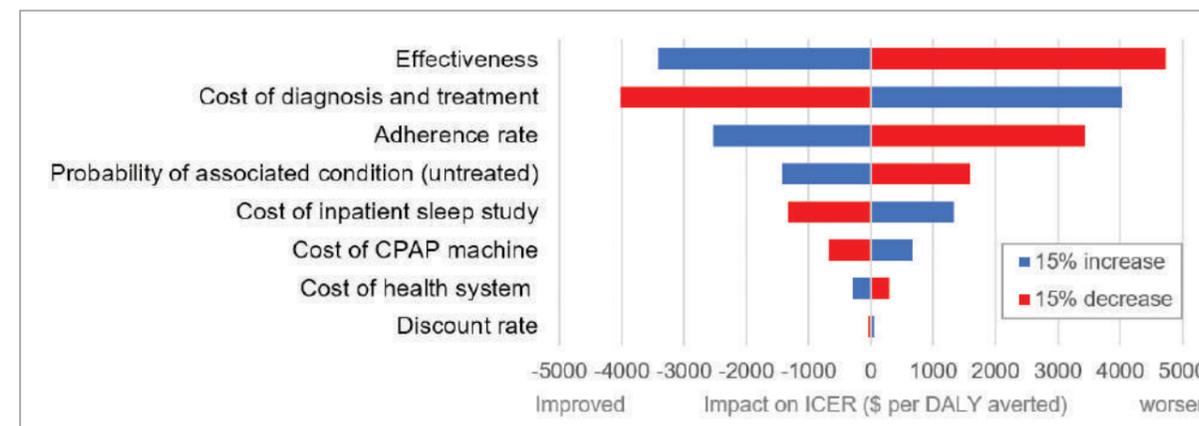
CPAP: Continuous positive airway pressure; DALYs: Disability adjusted life years; ICER; Incremental cost effectiveness ratio

Reference
1. Streatfeild J, Hillman D, Adams R, Mitchell S, Pezzullo L. Cost-effectiveness of continuous positive airway pressure therapy for obstructive sleep apnea: health care system and societal perspectives. Sleep J. 2019;42(12): zsz181.

Cost-effectiveness analysis of diabetic foot screening for ulcerations: AI-enhanced risk-tailored screening vs. routine annual screening

Dr Sun Yan and Dr Ang Yee Gary

HIGHLIGHTS

- Artificial Intelligence (AI)-enhanced risk-tailored screening for diabetic foot ulcers demonstrated cost savings of S$856 per patient with a negligible loss of quality-adjusted life years over a lifetime.

- Implementation of AI-enhanced screening has the potential to significantly reduce unnecessary screenings by approximately 6,709,013 and lower healthcare costs by approximately S$428 million for the half-million Singaporean diabetic population, while maintaining the quality of care compared to routine annual screening.

Introduction

Diabetic foot ulcers (DFUs) are a common complication among diabetic patients. Left untreated or poorly managed, DFUs can progress to the point where amputations are required, imposing substantial physical, emotional, and financial burdens on patients and their families. Evidence has shown that close monitoring, wound management, and patient education can reduce amputation rates by 49-85%. Current national guidelines recommend every 3-month screening for low-risk, moderate-risk and high-risk diabetic patients every 3, 6 and 12 months, placing a significant burden on the healthcare system given the high local prevalence of diabetes.

Our research aims to assess the economic feasibility and health outcomes of integrating artificial intelligence (AI)-enhanced screening to reduce unnecessary screenings among low-risk diabetic populations. Our proposed approach involves AI identifying super low-risk patients, enabling a lower screening frequency of every three years. For other low-risk patients, annual screenings are recommended. This novel AI-enhanced model aims to optimise resource allocation, achieving a balance between effective DFU prevention and reduced unnecessary screenings.

This study has two specific objectives: 1) to examine the lifelong direct medical costs and outcomes of AI-enhanced risk-tailored screening for DFUs among the diabetic population; and 2) to analyze the cost-effectiveness of AI-enhanced screening vs. routine annual screening for DFUs.

Methods

This was a cost-effectiveness analysis using a Markov state transition model with six states (low-risk diabetic population, DFU, minor lower extremity amputation (LEA), major LEA, and death) to simulate DFU disease progression. State transition probabilities were estimated from a literature review if they were not available in local data. Costs were estimated from local data. A cohort of 0.5 million simulated low-risk diabetic patients were followed up until death to evaluate their lifelong direct medical costs and clinical outcomes under two different screening strategies. The simulation was conducted for 40 years, with each year representing one simulation cycle.

The incremental cost-effectiveness ratio (ICER) was calculated to evaluate the cost-effectiveness of the two screening strategies. Cost analysis was conducted from the payer's perspective, with costs defined as the gross charge to patients/payers before subsidy, extracted from institutional financial data. Only direct medical costs were included in this analysis due to a lack of data on indirect costs. Effectiveness was measured by quality-adjusted life years (QALYs), with estimates for each disease state derived from local data.

Results

Estimates suggest that there are approximately 500,000 low-risk diabetic patients, with an average age of diabetes onset at about 50 years old in Singapore. These patients were simulated for life in this study. Their lifelong costs, clinical outcomes (i.e., DFU, minor & major LEA, or death), and cost-effectiveness were evaluated under the two screening scenarios, with the results shown in **Table 1**.

Table 1. Comparison of cost and effectiveness: annual yearly screening vs. AI risk tailored screening

Approach	Cost per patient	QALYs per patient	Total screens done	Total minor LEA	Total major LEA	Total death
Routine annual screening	S$33,455	23.9741	11,178,861	17,582	8,423	466,966
AI-enhanced screening	S$32,599	23.9761	4,396,830	17,599	8,461	467,017
Difference in 0.5M diabetes population	⬇ S$428M (total cost)	⬇ 0.001	⬇ 6,709,013	⬆ 17	⬆ 38	⬆ 51

AI: artificial intelligence; LEA: lower extremity amputation; QALY: quality-adjusted life year

AI-enhanced screening reduced healthcare costs by S$428 million for a diabetic population of 0.5 million in Singapore compared with routine annual screening, without compromising the quality of care. Annual screening only prevented 17 more minor LEAs, 38 more major LEAs and 51 deaths over 40 years in the Singaporean population. Per patient, AI-enhanced screening on average costed S$856 less (standard error, SE: S$16) at a loss of only 0.001 QALYs lifelong (SE: 0.0042 QALYs), suggesting cost savings at negligible impact to patients.

Conclusions

The proposed AI-enhanced risk-tailored screening can help reduce about 6,709,013 unnecessary screenings and healthcare costs of about S$428 million over 40 years for half a million Singaporean diabetic population without compromising the quality of care compared with routine annual screening.

Cost-effectiveness of screening for chronic kidney disease in the general adult population: A systematic review

Dr Yeo See Cheng[1], Dr Wang Hankun[1], Dr Ang Yee Gary, Dr Lim Chee Kong[2], Dr Ooi Xi Yan[1]

[1] Department of Renal Medicine, Tan Tock Seng Hospital
[2] Clinical Services, National Healthcare Group Polyclinics

HIGHLIGHTS

- Chronic Kidney Disease (CKD) screening shows significant variability in cost-effectiveness across different studies.

- The financial viability of CKD screening is influenced by treatment effectiveness, CKD prevalence, cost of treatment, and the discount rate.

Introduction

Chronic kidney disease (CKD) is a significant public health problem, with rising incidence and prevalence worldwide, and is associated with increased morbidity and mortality. Early identification and treatment of CKD can slow its progression and prevent complications. However, it is not clear whether CKD screening is cost-effective. The aim of this study was to conduct a systematic review of the cost-effectiveness of CKD screening strategies in general adult populations worldwide, and to identify factors, setting and drivers of cost-effectiveness in CKD screening.

Methods

Studies examining the cost-effectiveness of CKD screening in the general adult population were identified by systematic literature search on electronic databases (MEDLINE OVID, Embase, Cochrane Library and Web of Science) for peer-reviewed publications, hand-searched reference lists and grey literature of relevant sites, focusing on the following themes: (i) CKD, (ii) screening and (iii) cost-effectiveness. Studies comprising health economic evaluations performed for CKD screening strategies, compared with no CKD screening or usual-care strategy in adult individuals, were included. Study characteristics, model assumptions and CKD screening strategies of selected studies were identified. The primary outcome of interest was the incremental cost-effectiveness ratio (ICER) of CKD screening, in cost per quality-adjusted life year (QALY) and life-year gained (LYG), expressed in 2022 US dollars equivalent.

Results

Twenty-one studies were identified (**Figure 1**), examining CKD screening in general and targeted populations. The cost-effectiveness of screening for CKD was found to vary widely across different studies, with ICERs ranging from $113 to 430,595, with a median of $26,662 per QALY and from $6,516 to 38,372, with a median of $29,112 per LYG. Based on the pre-defined cost-effectiveness threshold of $50 000 per QALY, the majority of the studies found CKD screening to be cost-effective.

CKD screening was especially cost-effective in those with diabetes ($113 to $42,359, with a median of $27,471 per QALY) and ethnic groups identified to be higher risk of CKD development or progression ($23,902 per QALY in African American adults and $21, 285 per QALY in Canadian indigenous adults), as indicated

by a lower ICER. Additionally, the cost-effectiveness of CKD screening improved if it was performed in older adults, populations with higher CKD risk scores, or when setting a higher albuminuria detection threshold or increasing the interval between screening. In contrast, CKD screening was not cost-effective in populations without diabetes and hypertension (ICERs range from $117,769 to $1,792,142, with a median of $202,761 per QALY). Treatment effectiveness, prevalence of CKD, cost of CKD treatment and discount rate were identified to be the most common influential drivers of the ICERs.
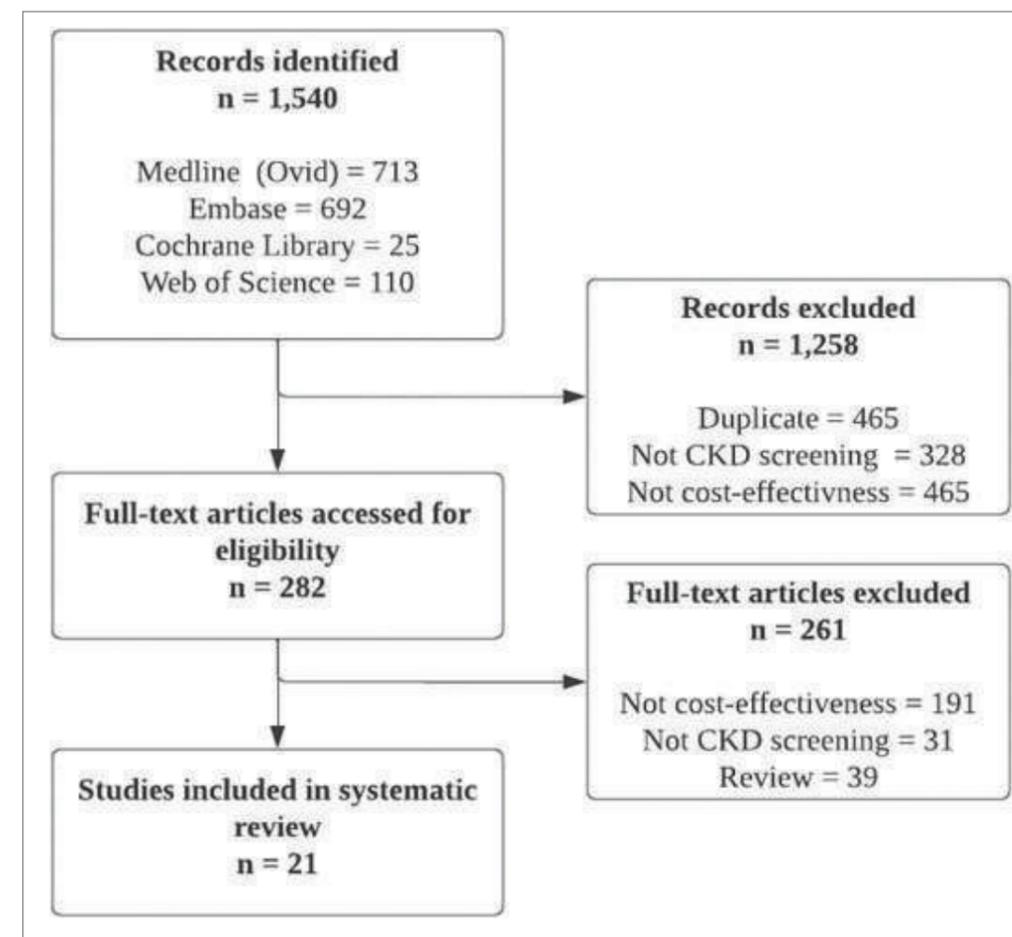
Figure 1. PRISMA Flow Diagram

CKD: chronic kidney disease

Conclusions

Screening for CKD is especially cost-effective in patients with diabetes and high-risk ethnic groups, but not in populations without diabetes and hypertension. Increasing the age of screening, screening interval or albuminuria detection threshold, or selection of population based on CKD risk scores, may increase cost-effectiveness of CKD screening, while treatment effectiveness, prevalence of CKD, cost of CKD treatment and discount rate were influential drivers of the cost-effectiveness.

Publications

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3. Lim JT, Choo ELW, Janhavi A, Tan KB, **Abisheganaden J**, Dickens B. Density forecasting of conjunctivitis burden using high-dimensional environmental time series data. Epidemics. 2023 Sep;44:100694. doi: 10.1016/j.epidem.2023.100694. Epub 2023 Jun 3.

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6. Yeo SC, Wang H, **Ang YG**, Lim CK, Ooi XY. Cost-effectiveness of screening for chronic kidney disease in the general adult population: a systematic review. Clin Kidney J. 2023 Jun 12;17(1):sfad137. doi: 10.1093/ckj/sfad137.

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Grants Awarded

2023 – 2025

Elucidating effectiveness, perception and barriers of primary eye care model in Singapore

$129,800

NMRC Population Health Research Grant - New Investigator Grant (PHRG-NIG)

Dr Yip Wan Fen (PI)
Dr Joseph Antonio D. Molina
Dr Michelle Jessica Pereira
Dr Tan Woan Shin
Vivien Yip (NHGEI, TTSH)
Teow Kiok Liang
Ding Si Yan (NHGP)

Jonathan Foo (NHGP)
Koh Yan Tong (NHGEI, TTSH)
Lim Tock Han (NHGEI, TTSH)
Quek Zuo Ling (NHGEI, TTSH)
Vernon Yong (NHGEI, TTSH)
Wong Hon Tym (NHGEI, TTSH)
Rosalynn Siantar (NHGEI, TTSH)

2023 – 2026

Integration of a prognostic tool for advanced dementia

$1 million

Temasek Foundation

Dr Allyn Hum (TTSH) (PI)
A/Prof Ding Yew Yoong (GERI)
Dr Tan Woan Shin
Dr Robyn Tan (NUS)
Dr Sun Yan

A/Prof Wu Huei Yaw (WHC)
Palvinder Kaur
Palvannan R. K.
Dr Noorhazalina Bte Ali (TTSH)

2023 – 2025

Automated diabetes foot screening device to improve early detection of foot complications in persons with diabetes

$13,000

NHG CMTI CiPP Grant

Dr Ang Yee Gary

Conference Awards and Presentations

May 2023

Biomedical Engineering Society 16th Scientific Meeting 2023

Artificial Intelligence-powered screening system for circulatory problems in people with diabetes using thermograph: improving early detection and treatment of foot complications

Oral Presentation - Gold Award

Dr Ang Yee Gary

8th International Advance Care Planning (ACP-i) Conference 2023

Associations of Advance Care Plans with end-of-life healthcare utilisation of home ventilation patients

Oral Presentation

Dr Michelle Jessica Pereira, Chieh Pann Pei, Siew Leong Kit, Dr Joseph Antonio D. Molina, Nicole Kow Mei Ting, Sun Tao, Dr Chan Yeow, Dr Tan Woan Shin

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Implementing Advance Care Planning in acute hospitals: early lessons and outcomes

Invited Speaker

Dr Tan Woan Shin

Evaluating the impact of a virtual training programme for Advance Care Planning facilitation in nursing homes in Singapore

Oral Presentation

Sheryl Ng Hui Xian, Joanne Selva Retnam, Roland Chong, Linda Yiu, Dr Raymond Ng, Dr Tan Woan Shin, Dr Adeline Lam

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Engagement with Advance Care Planning and level of decisional conflict among nursing home residents and their next-of-kin in Singapore

Poster

Sheryl Ng Hui Xian, Joanne Selva Retnam, Roland Chong, Linda Yiu, Dr Raymond Ng, Dr Tan Woan Shin, Dr Adeline Lam

August 2023

International Conference on AI in Medicine (iAIM) 2023

Harnessing BERTs for screening of studies for systematic reviews

Poster

Teow Kiok Liang, Dr Ang Yee Gary, Sheryl Ng Hui Xian

September 2023

2023 Innovation Ignition Challenge for Young Entrepreneurs

KeepFeet: Saving limbs through thermography-based foot screening

Oral Presentation - Merit Award

Dr Ang Yee Gary, Bhadhri, Nicholas

October 2023

15th Asia Pacific Hospice Palliative Care Conference

Risk factors for all-cause short-term mortality in patients with end stage renal disease: a scoping review

Poster - Best Poster Award

Dr Yip Wan Fen, Sheryl Ng Hui Xian, Palvinder Kaur, Dr Pradeep Paul George, Dr Jennifer Guan Huey Chen, Dr Lee Guozhang, Dr Timothy Koh Jee Kam, Dr Tan Woan Shin, Dr Allyn Hum

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Development of the PROgnostic Model for End-stage Lung disease (PRO-MEL)

Oral Presentation

Sheryl Ng Hui Xian, Dr Chai Gin Tsen, Palvinder Kaur, Low Zhi Jun, Jermain Chu, Tey Lee Hung, Dr Chiam Zi Yan, Dr Palvannan Kannapiran, Dr Neo Han Yee, Dr Tan Woan Shin, Dr Allyn Hum

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Mortality risk factors for patients with end-stage heart failure – a scoping review of the literature

Poster

Palvinder Kaur, Dr Pradeep Paul George, Sheryl Ng Hui Xian, Dr Yip Wan Fen, Eric Chua Siang Seng, Ri Yin Tay, Joyce Tan, Jermain Chu, Low Zhi Jun, Tey Lee Hung, Dr Violet Hoon, Dr Tan Chong Keat, Dr Laurence Tan, Dr Aw Chia Hui, Dr Tan Woan Shin, Dr Allyn Hum

Singapore Mental Health Conference 2023

Association of social isolation and depressive symptoms with workplace productivity loss: A population-based study

Poster

Joey Ha Wei Yee, Dr Yip Wan Fen, Ge Lixia, Dr Yap Chun Wei, Dr Michelle Jessica Pereira

Singapore Health & Biomedical Congress 2023

Barriers to participation in Advance Care Planning for next-of-kin of nursing home residents: a multi-method evaluation

Poster - Best Poster Award (Health Services Research): Gold

Sheryl Ng Hui Xian, Dr Tan Woan Shin, Joanne Selva Retnam, Roland Chong, Linda Yiu, Raymond Ng, Dr Adeline Lam

Home Ventilation and Respiratory Support Service Patients – where do they pass away?

Poster - Best Poster Award (Health Services Research): Silver

Dr Michelle Jessica Pereira, Chieh Pann Pei, Dr Joseph Antonio D. Molina, Tay Riyin, Sun Tao, Dr Adrian Tan Kok Heng, Dr Chan Yeow, Dr Tan Woan Shin

Survival analysis of home ventilation patients enabled by timeline visualisation

Oral Presentation - Singapore Young Investigator Award: Merit (Health Services Research)

Joey Ha Wei Yee, Reuben Ong Rong Ji, Dr Michelle Jessica Pereira, Dr Joseph Antonio D. Molina, Dr Tan Geak Poh, Dr Adrian Tan Kok Heng, Dr Kor Ai Ching, Soon Hse Yin Lydia, Sun Tao, Dr Chan Yeow

Effectiveness of the Diabetic Foot in Primary and Tertiary (DEFINITE) Care Programme: A historical control study

Poster

Ge Lixia, Dr Ang Yee Gary, Dr Joseph Antonio D. Molina, Dr Sun Yan, Dr Elaine Tan, Dr Liew Huiling, Dr Dexter Chan Yak Seng, Dr Joseph Lo Zhiwen

Measuring school children's health activation: using cognitive interviewing to refine instrument items

Poster

Ge Lixia, Dr Loke Hsi Yen, Ramakrishnan Karthigayan, Foo Hui Ting, Marcus Tang Chee Wei, Rochelle Chua Ming Jie, Dr Joseph Antonio D. Molina, Dr Ong Chin Fung

Using a Large Language Model to aid abstract screening in systematic reviews

Oral Presentation

Teow Kiok Liang, Dr Ang Yee Gary, Sheryl Ng Hui Xian

Self-reported physical function limitations as a mediator in the association between age and incident falls

Poster

Dr Yip Wan Fen, Ge Lixia, Dr Heng Bee Hoon, Dr Tan Woan Shin

Eyes on AI: Unravelling ChatGPT's potential in summarising qualitative in-depth interviews

Poster

Kon Mei Hui Adeline, Dr Michelle Jessica Pereira, Dr Joseph Antonio D. Molina, Vivien Yip, Dr Heng Bee Hoon, Dr John Abisheganaden, Dr Yip Wan Fen

Clinical feasibility of a mobile app for inter-scale conversion of thyroid function tests

Poster

Dr Meng Fanwen, Dr Ang Yee Gary, Puay Kiat Chionh, Dr Melvin Khee Shing Leow

Training and mentoring of nursing home staff in Advance Care Planning facilitation: a multi-method evaluation

Poster

Sheryl Ng Hui Xian, Dr Tan Woan Shin, Joanne Selva Retnam, Roland Chong, Linda Yiu, Dr Raymond Ng, Dr Adeline Lam

Singapore Health & Biomedical Congress 2023

An exploration of ventilation withdrawal discussions among Home Ventilation and Respiratory Support Service (HVRSS) patients

Poster

Michio Apollos Tan Abigail, Dr Michelle Jessica Pereira, Dr Joseph Antonio De Castro Molina, Dr Yip Wan Fen, Chieh Pann Pei, Tay Riyin, Sun Tao, Dr Chan Yeow, Dr Tan Woan Shin

What patient specific factors can potentially affect whether patients with knee OA attend physiotherapy?

Poster

Cheok Chi Min Ryan, Lim Chien Joo, Dr Bryan Tan Yijia, Dr Pua Yong Hao, Michio Apollos Tan Abigail, Dr Michelle Jessica Pereira

Transcription and analysis of audio interviews using privacy preserving large language models (LLMs)

Poster

Dr Li Ruijie, Dr Ang Yee Gary, Tiffany Lim Si Hui, Dr John Abisheganaden

College of Humanities, Arts and Social Science (CoHASS) Graduate Conference 2023

Artificial Intelligence in healthcare: opportunities and challenges for the doctor-patient relationship

Oral Presentation

Dr Ang Yee Gary

3rd Singapore International Public Health Conference & 17th Singapore Public Health & Occupational Medicine Conference

Measuring school children's health activation: using cognitive interviewing to improve the development of the instrument

Poster

Ge Lixia, Dr Loke Hsi Yen, Ramakrishnan Karthigayan, Foo Hui Ting, Marcus Tang Chee Wei, Rochelle Chua Ming Jie, Dr Joseph Antonio D. Molina, Dr Ong Chin Fung

Factors influencing individuals' choice of a hospital or clinic: A cross sectional study in Singapore

Poster

Ge Lixia, Dr Yap Chun Wei, Teow Kiok Liang

AvoMD AI Clinical Pathways Hackathon 2023

ACE Diabetes foot screening guidelines

Clinical Solution, 2nd Most Popular Solution

Dr Ang Yee Gary, Saziye Yorulmaz Avsar

Asian Conference for Frailty and Sarcopenia

Health-related Quality of Life (HRQoL) among frail older patients: patients versus proxy-reported scores

Poster

Joey Ha Wei Yee, Dr Michelle Jessica Pereira, Dr Edward Chong, Dr Joseph Antonio D. Molina, Dr Lim Wee Shiong

November 2023

CAPE Allied Health Congress 2023

Creating ripples, waves or tides? How can HSR contribute to sustainable health outcomes for the population?

Invited speaker

Dr Michelle Jessica Pereira

ISPOR Europe 2023

The CONNACT Program for knee osteoarthritis can potentially lower 2-year costs of outpatient treatment

Poster - Research Presentation Award Finalist: Top 5%

Lim Chien Joo, Dr Bryan Tan Yijia, Dr Pua Yong Hao, **Dr Michelle Jessica Pereira**

AI Health Summit 2023

Analysing the conversational chain between user and chatbot based on LLM enriched with eczema education material

Poster

Reuben Ong, Dr Ang Yee Gary, Ge Lixia, Palvannan R.K., Dr Yew Yik Weng, Dr John Abisheganaden

THE TEAM

Prof John Abisheganaden
MBBS, MRCP, M.Med, FAMS, FRCP
Director and Senior Consultant
(Effective from October 2023)
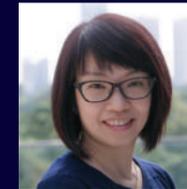
Ge Lixia
BMed (Nursing), MSc (Physiology),
MPH
Senior Research Analyst

Sheryl Ng Hui Xian
BSc (Hons) (Statistics), MPH
Senior Research Analyst

Tan Hwee Ling Jasmine
Adv Dip B. S. (Business Studies)
Senior Executive Assistant

Dr Heng Bee Hoon
MBBS, MSc (Public Health), FAMS
Senior Director (Completed term in
September 2023)

Joey Ha Wei Yee
BSocSci (Hons) (Economics)
Research Assistant

Reuben Ong
BA (Psychology) (Magna Cum Laude)
Executive

Dr Tan Woan Shin
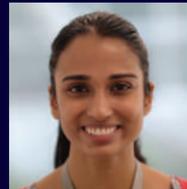BSocSc (Hons) (Economics), MSocSc
(Economics), PhD (Health Services
Research)
Head of Health System Performance &
Sustainability

A/Prof Ding Yew Yoong
MBBS, FRCP, FAMS, MPH, PhD
Visiting Consultant (Senior Consultant
& Clinical Associate Professor, Geriatric
Medicine, TTSH)

Palvinder Kaur
BSc (Biomedical), MSc (Public Health)
Principal Research Analyst

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