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Acute paediatrics tele-support for caregivers in Singapore: an initial experience with a prototype Chatbot: UPAL

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INTRODUCTION

When a child becomes unwell, caregivers and parents are frequently concerned about the potential severity of the illness. Depending on the presentation, nature and duration of the complaints, many of these acute paediatric conditions can be managed and monitored at home or managed by primary healthcare providers in the community.^(1,2) In today's highly connected world, caregivers and parents naturally turn to the Internet for quick and reliable information to guide them during this challenging period. However, they can be inundated with a barrage of health information while attempting to clarify their concerns and queries. This often confuses and generates more questions rather than provides direct answers to the anxious caregiver. These unanswered concerns that trouble caregivers of acutely ill children usually result in high paediatric attendances in the emergency department (ED), only to have the vast majority subsequently classified as 'non-urgent' or 'non-emergent' cases after medical triage and assessment.^(1,2) One of the strategies to better manage such non-urgent and non-emergent acute paediatric cases is the provision of an acute medical triage helpline for caregivers of acutely sick children.

KK Women's and Children's Hospital (KKH) operated a real-time 'Ask-A-Nurse' telephone service to address the acute concerns of parents about their child's health condition until a few years ago. In its peak, the hotline service addressed 30–50 calls a day and was generally well received by the community. However, the KKH Ask-A-Nurse service was discontinued because of staffing and funding issues. As part of its care transformation, KKH partnered with Ministry of Health (MOH) and Integrated Health Information System (iHIS), Singapore to develop and pilot a health chatbot to replace the Ask-A-Nurse service. The aim is to provide safe tele-support and accessibility to the community, as well as promote right siting of care for acute and urgent paediatric care needs.

In 2018, the collaboration among MOH, iHIS and KeyReply, a locally based vendor, culminated in the creation of KKH-Urgent Paediatric Advice Line (KKH-UPAL), a paediatric medical triaging chatbot to address the acute paediatric needs of parents and caregivers. KKH-UPAL was officially launched on 17 June 2019. In this paper, we describe our initial experience with developing and setting up of this prototype health chatbot for acute paediatric care and tele-support in Singapore, including the lessons learnt, and share the forthcoming plans for UPAL.

KKH-UPAL: YOUR BEST PAL FOR URGENT PAEDIATRIC ADVICE

KKH-UPAL is a health chatbot pilot online service for parents and caregivers of children seeking advice for common paediatric conditions, with the aim of reducing non-urgent and non-emergent emergency department attendances. By reducing these unnecessary attendances, appropriate patients will have shorter waiting time, along with decreased exposure to potential infectious microorganisms. The healthcare team is also able to focus on patients that require higher acuity of care and provide timely management.

Development of UPAL

The UPAL pilot was implemented in two phases (Fig. 1). Phase 1, launched on 17 June 2019, was a text-based live chat that allowed parents and caregivers to enquire about their children's conditions and presenting complaint. Besides text-based function, users were also able to send pictures of enquiries in real time. The main aim during this phase was to understand the key concerns and chief complaints that users had. The live agent, usually a nurse or a doctor, was able to respond to public queries via live chat. This required the live agent to be at the work desk at all times in order to attend to users promptly. Algorithms to common conditions such as fever,

vomiting, diarrhoea, cough and trauma (including physical injury, toxic ingestion of drugs or medication overdose, drowning, burns, animal bites and ingestion of foreign bodies) were drawn up to guide live chat agents on their responses and for artificial intelligence (AI) training at a later phase. This phase gave us an understanding of the common conditions that presented via a health chatbot channel and the common keywords used to seek advice, and helped us to map common queries to key illness areas to train the bot. In Phase 1, the chatbot was manned from 8 am to 11 pm daily. This required two staff members (a combination of nurses and doctors) to man the chatbot across two shifts (8 am to 5 pm, 5 pm to 11 pm) in a day. The chatbot was primarily manned by emergency trained nurses with doctors on standby for escalation of queries. In this phase, around 30% of users were directed to the ED, while the remaining were directed to the various primary care providers or advised to monitor at home with red flags advice given. An exceedingly small number of users (about 1%) were advised to call for an ambulance.

In February 2020, Phase 2 of UPAL was launched, and the chatbot served as the first point of contact for patients. The chatbot was enhanced by supervised machine learning capability with the text data collected in Phase 1. Patients could now receive care tips and advice for conditions that are non-emergency, or advice to visit a primary care doctor or the Children's ED, depending on the severity of the condition. The healthcare team in the Children's ED only attended to live chat requests when needed or when the chatbot was unable to address these queries appropriately. In this phase, the manpower requirements to attend to the chatbot was greatly reduced. Nurses from the emergency team continued to be on standby from 8 am to 11 pm; however, they were able to continue their normal clinical work and attended to the chats only when the bot was unable to address queries from users. Similar to phase 1, the chatbot was primarily manned by emergency trained nurses with doctors on standby for escalation of queries. The bot has been able to address

more than 96% of queries from users, with < 4% of escalations to nurses (4–6 chats per day). This resulted in a significant reduction in manpower needs.

Fig. 1 Chart shows the development of UPAL.

Process of training the chatbot

As part of the pilot project, we initially intended to link UPAL to an online application programming interface (API) known as 'Infermedica', which would function as a medical knowledge database to enhance and strengthen the developing AI abilities of UPAL. However, we found that most of the reasoning algorithms and pathways were not suitable or applicable for our local healthcare setting and patient population. Thus, we developed our own algorithms in line with our local clinical practice guidelines.

Using these algorithms as a base, the chatbot functioned like a human brain. When a user asks a question, the question is processed by the natural language processing (NLP) engine – the 'brain' of chatbot – which then returns a response. Should a suitable answer not be found, there is a fallback step where the chatbot will search from a pre-prepared 'frequently asked questions' (FAQ) medical knowledge base. If this also fails, the question will be escalated to the live agent.

Fig. 2 illustrates the message flow when the chatbot receives a question.

Fig. 2 Illustration shows the message flow when the chatbot receives a question.

The process for an NLP engine to understand medical queries from users is not the easiest, especially at the starting phase of the project. For example, the chatbot might not be able to interpret lengthy messages with multiple contexts, such as having two or more chief complaints in a single lengthy message. To bridge the ‘language barrier’ between the patient and the chatbot, there was constant reviewing and labelling of the dataset between KeyReply and the healthcare team. In instances where the chatbot was not able to understand questions that were correctly phrased, the team would add new keyword expressions or ‘utterances’ into the chatbot dataset dictionary. We also introduced a checking process for complex queries where the bot would ask a question based on its interpretation of the query before giving its reply. Colloquial language (commonly known in Singapore as ‘Singlish’, which is a mix of English with Mandarin and Malay) was included to enable the chatbot to address questions phrased in the local context. In addition, better menus, dialogue flows and suggestions to help users phrase questions in a way the chatbot

could understand were designed to better direct and assist users to obtain appropriate responses. Conflicting responses had to be reviewed and removed, for example, if the chatbot gave an incorrect answer to a question not within its knowledge base instead of escalating the question. The healthcare team has worked closely with KeyReply to increase the knowledge base and coverage of illnesses of the chatbot. The five most commonly asked questions by free text were related to minor trauma (27%), medication (14%), rashes (12%), diarrhoea (10%) and fever (10%), while the five most commonly selected clinical pathways with algorithms were fever (31%), trauma (19%), cough (18%), diarrhoea (7%) and vomiting (5%). After analysing common queries posed by UPAL users during the pilot phase, the team extended the medical database to handle queries on other key areas, such as infant feeding and crying, constipation, urinary tract infection, rashes, and common medications like antipyretics and antihistamines. During the COVID-19 pandemic, the team also incorporated specific advice to provide guidance on COVID-19-related queries and where to seek medical attention for COVID-19-related concerns. This had to be updated regularly to meet the constantly changing criteria as the pandemic developed.

To make the responses more helpful and meaningful for users, we provided links to patient information leaflets that contain more information on common paediatric conditions, home management principles and anticipatory guidance. ‘Small talk’ was also added to the conversation base to increase the human touch and emulate human interaction. During the review of the interactions between users and nurses from the pilot phase, the team observed the common small talk phrases used and added variations to the responses in order to “humanise” the chatbot.

Use of dashboards in UPAL

The healthcare team has been using a centralised dashboard (Fig. 3) provided by KeyReply for the live chat console, NLP training, content or response management and analytics review. Designated healthcare members are given a WhatsApp API account, which is an app-specific username and password to allow access to the dashboard. The live chat module is connected to a WhatsApp Business API account that triggers a notification on the live chat queue status, so that the healthcare team are notified of a live chat request.

With this workflow, UPAL nurses or doctors are able to focus on their full-time work and attend to the live chat requests on a need-to basis. This was especially important and useful in Phase 2, as notification to attend to the live chat was triggered when the chatbot was unable to resolve or respond to queries. The dashboard also displays the top questions asked and unanswered, which would enable the team to easily review the interactions between the chatbot and users. The training process of the UPAL chatbot was simplified to make it non-technical and user-friendly. The content management team is able to review the conversation on the same dashboard and train the NLP engine with new questions with a few button clicks.

System to track and improve UPAL

We set up a three-question feedback at the end of each live chat and chatbot conversation for users to provide feedback on their experience using the service. UPAL received helpful and good feedback over the one-year pilot, with high user-experience and recommendation rating. On qualitative review of the feedback, we noted that patients repeatedly fed back that UPAL saved them from unnecessary trips to the Children's ED (Figs. 4–6). Other than the ratings at the end of every live chat, users who were directed to bring their children to the ED for an assessment

provided their positive experience via our institutions' feedback channel. Qualitative feedback and comments – both positive and constructive – have helped us further improve UPAL.

Feedback on Phase 1 was generally better than that on Phase 2. We postulate that this is because Phase 1 provided more direct and relevant human interactions compared to Phase 2. We also noted an increase in users during Phase 2, which coincided with the COVID-19 circuit breaker period. Parents were keen to avoid unnecessary hospital visits to limit potential exposure to the COVID-19 infection. With increased users, we managed to gather valuable feedback and improve the system regularly. Moving forward, with iterative retuning of the bot interaction, we are confident that feedback for Phase 2 will improve and be comparable to, if not better than, Phase 1.

Fig. 3 Screenshot shows an example of the UPAL analytics dashboard.

Fig. 4 Graph shows the monthly breakdown of usage since the launch of UPAL (17 June 2019 to 31 May 2020). The total chat sessions, which are more than the total users, suggest repeated usage of the chatbot. An increase in the number of chats from March 2020 coincided with increased public awareness and social media coverage, the surge in community cases of COVID-19 and the start of circuit breaker in April 2020.

Fig. 5 Chart shows user satisfaction with Phase 1 live chat services and examples of positive feedback received.

Fig. 6 Chart shows user satisfaction with Phase 2 chatbot and examples of feedback received.

DISCUSSION

Telemedicine, which is often used interchangeably with ‘telehealth’, refers to the systematic provision of healthcare services over physically separate environments via information and communications technology (ICT). The four main dimensions of telemedicine are tele-treatment or consultation, tele-monitoring, tele-collaboration and tele-support.⁽³⁻⁵⁾ Tele-support, in particular, refers to the use of online services for non-clinical (i.e. educational and administrative) purposes to support the patient and caregiver. Examples include health education, care administration and the use of treatment prompts in chronic disease management.⁽³⁻⁵⁾

A chatbot is a type of telehealth, more specifically tele-support. It is a software with AI that simulates a conversation or chat via messaging applications, websites, mobile apps or through the telephone.^(6,7) The chatbot analyses a request, identifies the intent and then proceeds to set up and compose a response accordingly through natural language processing. The response can be in the form of a text-based or verbal platform. Built into the chatbot are algorithms that help to address the requests and makes the subsequent appropriate responses. For conversations in chatbots to pass

muster as authentically human, the ‘Turing test’, as described and defined by Alan Turing in 1950, is a test of the ability of a machine to exhibit behaviour (or responses) in a way that is intellectually indistinguishable from that of a human being. In the mid-1960s, Dr Joseph Weizenbaum from the Massachusetts Institute of Technology created ELIZA, the first chatbot capable of meeting the Turing test.⁽⁸⁻¹⁰⁾ Today, better known chatbots include Siri and Alexa.

Health chatbots can help in providing timely health advice for patients and families. They provide medical information and advice, leveraging on technology and the tech savvy-ness of parents and caregivers, to better provide good medical advice when a child falls sick. These medical chatbots could address queries concerning specific diseases, such as FAQ and advice for patients with inborn errors of metabolism or more general health queries related to urgent or emergency medical conditions. Fig. 7 shows a simplified representation of how a chatbot works.

Fig. 7 Simplified representation shows how a chatbot works.

Types of health chatbots

The Internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects and people that are provided with unique identifiers, with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.^(11,12)

Powering and driving IoT and ICT is AI. A critical element of AI development is therefore machine learning (ML), which uses algorithms and statistical models to carry out specific tasks without using explicit instructions, relying on patterns and inferences instead. Performing ML involves creating a model, which is trained on preliminary training data. The system can then process additional data to make predictions.⁽¹³⁻¹⁷⁾ As Khanna et al elegantly puts it, the meaning of intelligence in a machine comprises both quantitative and qualitative dimensions. It is founded on arithmetic operations and computations and progresses to applying logic and making comparisons and reasoning. There must be constant learning from constant sensing and subsequent perception. The ultimate endpoint is the creation of ‘consciousness’.⁽¹⁸⁾ AI helps to boost efficiencies, performance and productivity in various ways. In the near future, we predict that AI will be an integral part of Singapore’s healthcare system, to help doctors make better decisions, design early intervention programmes and improve care pathways for patients using predictive modelling.

Chatbots are a form of ‘smart’ ICT that enables specific queries to be addressed and answered and relevant information to be conveyed. They have the potential to be smart because of the use of AI and the sophistication of the algorithm created in its neural architectural structure.^(8-10,19) Medical chatbots are a vital component in this suite of devices and services that can drive IoT in the medical and healthcare sector. Medical chatbots can serve the general public and patients in the community as well as assist healthcare providers and professionals.

While it is relatively easier to deliver relevant information and advice via the chatbot circuitry and through simple algorithmic processing, it is far more difficult to achieve a more nuanced, higher level and sophisticated response. This kind of response will require aggregated medical information that is soundly reasoned and integrated, that can truly lead to a diagnosis (differential or otherwise) and treatment and care recommendations through AI, which is robustly

and rigorously tried and tested. In short, health chatbots can be a simple ‘advice or informational’ health chatbot (which is what UPAL currently is) or, if developed with more sophistication, an advanced health chatbot that is capable of arriving at diagnosis and formulating treatment and care plans. Fig. 8 shows a pictorial illustration of the levels of information processed and delivered by advice and informational medical chatbots vs. advanced medical chatbots, while Box 1 describes the information delivered by the different types of health chatbots.

Up to now, we have not yet used true machine learning in UPAL. Currently, when we review and learn from the initial iterations in UPAL, cull the necessary leaning data and information and then proceed to strengthen the algorithms and processes, we are conducting ‘machine training’ or ‘machine teaching’ by human endeavours, and not true, hard-core machine learning.

Fig. 8 Chart shows the levels of information processed and delivered by medical chatbots.

Box 1. Types of health chatbots and their descriptions:**Target audience**

- **For public:** Serves specific patient population, e.g. pregnancy chatbot; Urgent Paediatric Advice Line (UPAL)
- **For professional:** Serves the needs of medical healthcare professionals; acts as a reference to guide professionals on patient care and how to better manage patients

Level of information processed and delivered

- **Advice and informational medical chatbot:** Provides straight-forward advice and information to query
- **Advanced medical chatbot:** Integrated and reasoned response to query, leading to diagnosis, treatment and care plans

Quality and safety of health chatbots

Health chatbots must be well designed and effective to serve the needs of the population in question. As the general health and wellbeing (and possible serious morbidity) of patients, including children, is implicated, the implementation of health chatbots must be thoroughly evaluated before being pushed out to the public domain. As Nadarzynski et al rightly puts it, medical or health chatbots must “*employ user-centered and theory-based approaches addressing patients’ concerns and optimising user experience in order to achieve the best uptake and utilization.*” User receptivity will be enhanced as long as patients’ perspectives, motivation and capabilities are taken into account when developing and assessing the effectiveness of health chatbots using AI-led algorithms.⁽²⁰⁾

Equally, if not more, important, chatbots must not allow malicious attacks and pose cybersecurity risks to the users. These ‘bad bots’ interact with applications in the same way that a

legitimate user would, making them harder to detect. These bots enable high-speed abuse, misuse and attacks on websites and APIs. They allow attackers, unsavoury competitors and fraudsters to perform a wide array of malicious activities.⁽²¹⁾ It has been estimated that, while more than 55% of the bots used in healthcare are good bots, almost 25% of healthcare bots are bad. Overall, healthcare is number four in the creation of bad bots. Much care must be taken to ensure medical chatbots, especially if they eventually interface and integrate with sensitive electronic health records, pass muster and penetration testing.⁽²¹⁾ Penetration testing, pen testing or ethical hacking is the practice of testing a computer system, network or web application to find security vulnerabilities that an attacker could exploit.⁽²²⁾

Role of health chatbot in healthcare communities and paediatrics

Telehealth, including telecommunications and virtual technology, can help reshape and improve the delivery of child health. The aim for health chatbots is to provide the initial professional advice, either via text messaging or voice calls, with backup from a pool of trained medical staff.⁽²³⁾

During the COVID-19 pandemic, many medical and health chatbots have been quickly set up to urgently assess and triage suspected COVID-19 cases. It attests to the power of chatbots, the receptivity toward them, and the ubiquitous role they can play to help support and assist the general population, especially during such challenging times for population health.^(24,25) KKH-UPAL also developed general advisory and guidance for parents regarding COVID-19 and where to seek medical advice if they had concerns.

One example of a successful chatbot in the United States is Tess, a coaching chatbot to manage obesity and pre-diabetes mellitus in adolescents that utilises behavioural intervention technologies.^(26,27) Tess engages adolescents with chats or brief conversations using customised

integrative support, psychoeducation and interventions through social media – short messaging service (SMS), text messaging and Facebook Messenger. The initial evaluation of Tess is promising; in adolescent patients, the reported usefulness rating was 96% of the time with positive experience rating progressing toward the goal of 81%. The authors wrote: “*As a partner to clinicians, Tess can continue the therapeutic interaction outside office hours while maintaining patient satisfaction.*”

Future directions and potential of UPAL

UPAL can be enhanced to ensure seamless and right siting of care for the acute paediatric patient, as well as further developed to truly integrate it as a smart component in the healthcare ecosystem of the 21st century.

(1) Integration with geographical information system trackers and linkup to healthcare facility

Linking UPAL with a GPS tracker that is merged with locations of healthcare facilities in the vicinity of the UPAL user will enable the system to match the nearest medical facility to the UPAL user. The system can then direct the caregiver to the most appropriate healthcare facility in the area. The system can also alert the nearby healthcare facility of the imminent arrival of the patient should the UPAL user choose to select this recommended healthcare facility.

(2) Integration with the patient's electronic health records

Information collected from UPAL can flow into the patient's electronic health records. This will document real-time information entered by the patient and/or caregiver that will represent their actual concerns and views. It can ultimately provide a more holistic and comprehensive

documentation and record of the acute medical episode.

(3) Integration with wireless devices and biosensors

The advent of wireless devices and biosensors, particularly those that monitor and capture vital signs, will increasingly play a pivotal role in child health in the coming years. Medical chatbots will be further enhanced when these wireless biosensors are used in the chatbot flow and algorithm. Such biosensors are becoming increasingly common and available for day-to-day and routine use. While consumer-grade devices, such as FitBit and Apple Watch, serve general consumer needs to monitor and track overall health, medical-grade devices can play an important role in paediatric health in healthcare institutions and the community.

RAPID (real-time adaptive and predictive indicator of deterioration) is a recent development by Birmingham Children's Hospital using real-time monitoring technology pioneered by McLaren Formula One technology. Patch devices with wireless technology continually monitor patient data (e.g. heart rate, breathing rate, oxygen levels) and upload the data onto an analytic platform.⁽²⁸⁻³⁰⁾ Algorithms can utilise these real-time data in a prompt and timely fashion to enhance care. These algorithms can be constantly refined and improved through ML. Routing biosensor data from these smart biosensors and making these vital signs data part of the informational and algorithmic processing of health chatbots will enable the chatbot to provide even more patient-specific and patient-centred advice, and in the case of advanced medical chatbots, they lend greater clarity and robustness in the recommended diagnosis, treatment and care plans.⁽³⁰⁾

Medical chatbots in health services and public health research

Equally important and significant from a public health standpoint, the amount of information and data that can be collected and accrued through medical chatbots and telehealth as a whole will enable us to better understand the needs and concerns of users of individual medical chatbots. The ‘big data’ and knowledge gathered will help us to better plan and improve care for our patients, both individually and as a community. Learnings from medical chatbots can also help to inform health and health-related systems.⁽³¹⁾ For instance, the American Academy of Pediatrics recently set up a paediatric telehealth research network, SPROUT (Supporting Pediatric Research on Outcomes and Utilization of Telehealth).⁽³²⁾ Such platforms will enable us to learn and share information and knowledge across the community, as well as constantly improve the overall health and care of children.

CONCLUSION

Health chatbots can help to improve the health literacy and knowledge of our community. At its most basic level, by providing information and advice like in UPAL, it allows caregivers and parents to better understand the acute needs of their sick child and offers quick, curated and sound advice that is tailored to the specific needs and concerns of the child. Our initial experience of setting up UPAL and launching it to the community has been favourable. High and repeated usage validates chatbot messaging as a well-accepted communication channel. Positive responses from the public with consistently high user experience rating and recommendation scores show that UPAL is an effective virtual form of patient communication. Many users also indicated that UPAL reduces their need for a trip to the ED. We believe that UPAL has much potential as we further hone and develop it to meet the healthcare needs and concerns in our paediatric community.

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