Review Article

Use of speech-to-text technology for documentation by healthcare providers

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ABSTRACT

Medical records are a critical component of a patient's treatment. However, documentation of patient-related information is considered a secondary activity in the provision of healthcare services, often leading to incomplete medical records and patient data of low quality. Advances in information technology (IT) in the health system and registration of information in electronic health records (EHR) using speech-to-text conversion software have facilitated service delivery. This narrative review is a literature search with the help of libraries, books, conference proceedings, databases of Science Direct, PubMed, Proquest, Springer, SID (Scientific Information Database), and search engines such as Yahoo, and Google. I used the following keywords and their combinations: speech recognition, automatic report documentation, voice to text software, healthcare, information, and voice recognition. Due to lack of knowledge of other languages, I searched all texts in English or Persian with no time limits. Of a total of 70, only 42 articles were selected. Speech-to-text conversion technology offers opportunities to improve the documentation process of medical records, reduce cost and time of recording information, enhance the quality of documentation, improve the quality of services provided to patients, and support healthcare providers in legal matters. Healthcare providers should recognize the impact of this technology on service delivery.

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INTRODUCTION

The healthcare industry has seen major developments over the past decade with opportunities for better and more efficient delivery of services.[1] There are speech systems that understand human language. These systems help improve productivity and quality of documentation without any negative impact on users.[2,3]

Written documentation has numerous limitations, such as improper registration of data, illegibility and invalid data, which compromise the quality of medical records.[4,5] Safdari *et al.*,[6] quoting a report by the Institute of Medicine, USA, said that annually over 100 000 American citizens lose their lives due to 'documentation errors' and mainly because of 'poor medical documentation' such as illegible documentation, wrong interpretation or lack of coordination in registries. On the other hand, documentation is a stressor for doctors and patients. Some studies on written documentation confirm that the burden of manual documentation leads to higher dissatisfaction among doctors and nurses (57%) compared to other reasons such as long hours of work or low income of personnel.[6]

In healthcare, access to technologies such as speech-to-text conversion (as a method to improve documentation quality) can influence the quality of services and consequently the quality of life.[1] Use of such technologies in healthcare will push the demand for electronic health records (EHR) in institutions providing healthcare.[7] Medical professionals who do not have access to transcription services have to type their daily diaries which needs both typing skills and considerable time. Due to increase of participation in the care of patients during different processes, researchers who are interested in technology-based approaches seek ways to enhance the ability to document medical records in electronic form.[8] This technology is less expensive than other methods of clinical documentation such as dictation.[9] One major advantage of automatic reporting is quick access to written reports; however, for every special use, the system's vocabulary should have sufficient credibility.[10] This article aims to discuss the use of speech-to-text conversion software in healthcare documentation, and identify the benefits and challenges of its implementation.

METHODS

For this narrative review, I divided the work into three phases: literature collection, assessing and selection. I did the literature search with the help of libraries, books, conference proceedings, databases of Science Direct, PubMed, Proquest, Springer, Scientific Information Database (SID), and search engines such as Yahoo and Google. I used the following keywords and their combinations: speech recognition, automatic report documentation, voice to text software, health information and voice recognition. During July 2014, I searched for articles published between 1990 and 2014. Due to lack of knowledge of other languages, all texts were searched in English or Persian with no time limits. Over 70 articles were identified and assessed, of which 42 relevant articles were selected for detailed study.

RESULTS

Since 1930 when Homer Dudley from Bell Library proposed a model for speech analysis, speech recognition has changed from a simple technology to an advanced system with an ability to

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understand natural language.[11] The initial systems of speech recognition developed in the early 1970s were able to recognize only a set of discrete words. These systems had a limited vocabulary and the rate of error was high, the time needed was more compared to manual typing and hence the degree of acceptability was lower. However, in 1980 a system used a dictionary with hundreds of words.[12] Researchers at Stanford University found that despite weaknesses of the early speech recognition systems, advances in technology during 1998 led to systems that were able to perform better and understand continuous speech.[9]

A speech recognition system lets data enter into a computer (instead of typing with a keyboard or other tools) by speaking into a microphone. Thus, doctors enter their clinical data directly into computers.[12] Doctors who used this system before 1990 needed to pause after each word. Radiology and pathology departments were the first to adopt this system, because their performance was dependent on dictation—it had high costs and there was a delay in completing reports. In the traditional dictation method, the report was recorded by a technician and copied by others. This process usually lasted some days; therefore, when quick registration was needed, this method could not help. Prompt completion of clinical documents was important for improved coding, financial reimbursement and billing.[9]

Speech recognition technology has improved markedly over the past decade. A larger vocabulary, wireless speakers and separate detectors are examples of the progress made. Modern speech recognition systems have a high accuracy; however, a limiting aspect is speech integrity in terms of software performance.[13,14]

Before implementing such a system, some issues have to be considered. No system is completely accurate and users may face errors even after improving the dictionary and providing necessary training. Also, providing such a system at all workstations would reduce the time required for documentation. The quality of the dictionary used by the system influences its success.[9] The level of lexical items affects completion time.[15] Lack of proper access to these words will increase the time needed to complete documents.[9]

Health centres focus on systems that provide patient information and facilitate clinical reporting processes, and speech recognition systems can be suitably used for the purpose.[16] Using these technologies, health organizations are seeking ways to provide legible documents with lower costs and higher speed.[9]

How do speech-to-text conversion systems work?

The components of a speech-to-text conversion system include a microphone, sound card, vocabulary, speaker, language model and a speech recognition engine. The microphone and sound card change human analogue speech into digital waves. The recognition engine matches digital sounds and words via recognition codes. In order to match speech and vocabulary, 2–3 most probable words are identified for analysis.[1] Words are combinations of sounds that are called phonemes and the English dictionary has symbols for each phoneme. These symbols are used to describe vocabulary pronunciation and divide phonemes into vowels and consonants.[9] A basic vocabulary including 300 000 words and a speaker's profile connect the user's speech and creates text using the sound recognition engine.[1] A dictionary can be from 20 words to over 40 000 words. Dictionaries with more words can create problems in a system's accuracy.[17] Different approaches are used for speech recognition; the most successful one is a pattern-based approach which is applied in almost all modern systems. In this approach, speech is modelled based on some phonetic units such as word, syllable, phonology or phoneme. For recognition, these units are determined and put together in order to find the text that matches the speech.[6]

Pattern recognition applications aim to reduce the amount of computation and eliminate redundancies in speech signals through extraction of a limited number of parameters. Extracted parameters have to be appropriate for the intended application. In other words, for speech to be recognized independent of the speaker, the parameters have to be least sensitive to the spoken word of a particular language. On the other hand, for speaker-dependent applications such as speaker identity through speech it is better to extract speaker-dependent parameters such as tone, shape and acoustic length (Fig. 1).[6]

Five approaches that can be used for controlling and facilitating speech recognition are: use of separate words, dependent systems, number of dictionary lexical items, language grammar, and controlled environmental conditions. The five components of a speech recognition system are: sound recording and collecting devices, signal digital processing items, signal storage before processing, reference speech patterns, and machine pattern algorithms.[18]

Today, speech recognition technology is used in different

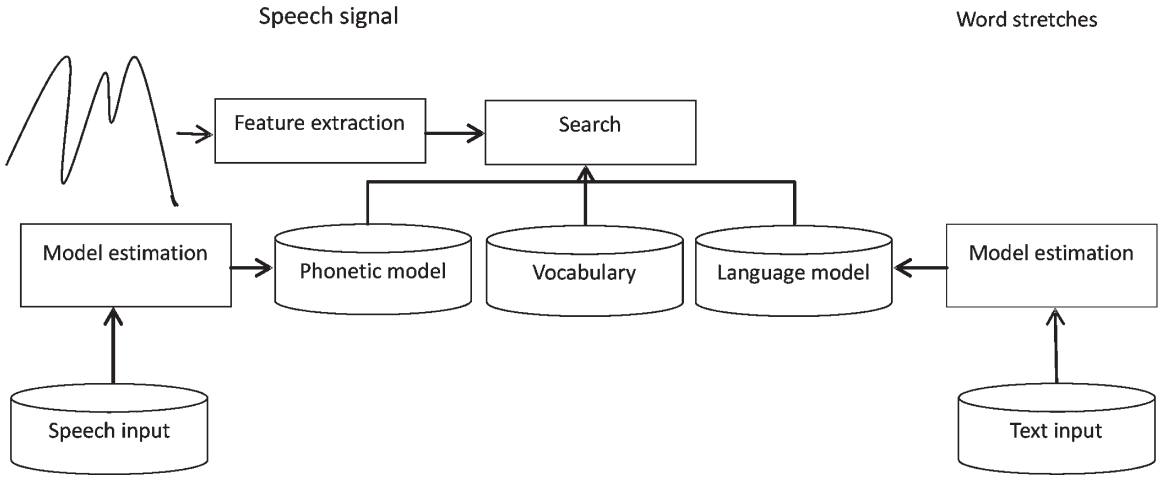

FIG 1. Steps of word recognition through speech recognition system with main components of a speech recognition system

areas. Speech recognition depends on five factors: speaker, speech, vocabulary, language grammar complexities and average vocabulary input. The effect of these elements can be reduced by standard tests and continuous recording sets. The speaker is the most influential element; however, accuracy of words does not mean their intelligibility by the system, because both speaker and system are affected by sound quality, background noise, speech domain and speed.[19]

Performance of speech recognition systems

Speech is a natural form of effective and comprehensive communication; however, it is not still widely accepted as an interface between humans and computers. Speech can be ideal where the human eyes and hands are busy, especially in patients' treatment.[17]

Speech recognition technology enables doctors to communicate easily with a computer. For example, this technology is important for dentists who find it difficult to use a keyboard and mouse while working. These systems need to maintain and understand a large number of idioms as opposed to the usual language. In general, limitations in the selection of vocabulary will reduce a therapist's ability in direct communication with the system during clinical care. This issue can be challenging for patients' EHR and clinical decision-making support systems.[20]

Expenses incurred on such systems depend on the quality of software and hardware (such as microphone and other factors). Documentation and editing with a sound recognition system is sometimes boring and cumbersome, particularly when strange names or words are used. Moreover, the system seems to have problems with small words such as 'and', punctuation, grammar and phrases. The use of special patterns can be helpful in the short term, for example in reports with repetitive items such as foetal ultrasound, mammography or chest X-ray. However, these patterns are less helpful for imaging studies which need unique explanations and different diagnoses (many technical words may be absent in the system lexical entry).[21]

The final goal of a speech recognition system is to develop the ability to hear like humans and show proper reaction. All speech recognition systems have one feature in common, which is 'the requirement of sound input'. These systems are divided into several categories based on the input provided:

- speech-to-text systems;
- speech-to-command systems; and
- speech-to-speech systems.

Moreover, some artificial neuronal networks are used for system improvement and innovation. Artificial neuronal networks can process information. The key element of this is a new structure for information processing. This system includes numerous integrated processing components (neurons) which cooperate to solve a problem. Artificial neuronal network uses examples for learning, in a manner similar to humans.[22]

Speech-to-text technology for EHR

Speech recognition software can potentially improve the speed and accuracy of data input into a health record and therefore eliminate a key barrier to the acceptance of EHR.[23] Speech recognition is a relatively new method for input of patient data. Healthcare organizations and clinics should assess different methods of data input to obtain high productivity and satisfaction.[24] According to the American Healthcare Information Management Association (AHIMA), the time needed to edit documents is twice that required for dictation.[20] Users who implement speech recognition system in healthcare refer to its obvious advantages in productivity and improvement of EHR documentation in 93% of cases. A major advantage of this technology is the use of computer macro commands (voice commands that enter into text).[25]

Two systems have been evaluated for speech recognition in healthcare in the German language. The accuracy of word recognition was 92%–94% one month after implementation of the system. System performance increased up to 97% for standardized texts. Speech recognition technology was cost-effective when reports were short, while no significant cost-effectiveness was observed for complete and comprehensive discharge reports. Text editing is time-consuming and the person editing it is the doctor who has dictated the report to the system.[26]

USE OF SPEECH-TO-TEXT TECHNOLOGY IN HEALTHCARE

In radiology

Radiologists play an important role in patient care. One of their important responsibilities is prompt and accurate transmission of radiology reports to doctors. Before the advent of the speech recognition system, radiologists had to edit reports input by typists before final reporting.[27] In 1989, a study showed that 63% of participants believed that patient records increased the burden of work without affecting the quality of healthcare.[28] Speech-to-text conversion technology was introduced to reduce the time needed between dictation and final reporting. One key disadvantage of these systems is errors which may include elimination, replacement, wrong words, or reports with confusing or incorrect sentences. Accurate dictation and correction of reports to minimize errors can be important in the management of patients. Some examples of these errors include: writing right instead of left, renal instead of adrenal, or hyper-intense instead of hypo-intense. Speech-to-text technology helps radiologists to interpret reports instead of dictating them. Moreover, reports are immediately available in picture archiving and communication systems (PACS).[27]

Speech recognition technology supports radiology reporting systems by reducing costs and saving time in preparation of photographs. The advantages of such a system are immediate recording (only 5 months after implementation of speech recognition system, 95% of reports were documented and edited in <1 hour) and reduction in documentation costs. Licht *et al.* showed that the least reduction in productivity is observed when speech recognition system is implemented before radiologists start their work and the most reduction in productivity is experienced when the system is implemented simultaneously with radiologists' daily work.[26] Antiles *et al.* from the radiology consulting group in Massachusetts general hospital showed that computerized speech recognition systems led to fewer expenses and more services. The hospital saved $530 000 during two years of using the system.[29] However, other studies indicated that speech recognition technology did not bring about similar results in clinical systems. For example, Pezzullo *et al.* showed that use of speech recognition system for preparing radiology reports in a non-scientific collection increases radiologists' frustration and reflects more errors in reports and higher expenses compared to ordinary transcription activities. Although speech recognition needs up to 24% shorter time compared to conventional methods, about 50% more time is spent compared to ordinary dictation.[30]

In pathology

Henricks *et al.* showed that the use of speech-to-text conversion

technology in description of specimens and final reporting in pathology facilitates data input, reduces copying expenses and improves workflow time.[31] It is important to develop frameworks (patterns) in order to implement this technology successfully. Copying is necessary in pathology information system where observations and diagnoses are recorded and reports are prepared referring to them. In surgical pathology, speech recognition technology improves workflow productivity, reduces delays in copying (transcription), and reduces the costs. A speech-to-text conversion system directly transforms pathology reports into electronic texts. If this system is integrated with surgical pathology information system through an interface, there is no need for transcription in surgical pathology information system.[31]

Kang *et al*. showed that use of this technology in pathology reduces production time, makes pathology reports available and improves the quality of services provided to patients. Moreover, patient security increases due to fewer errors in copying.[32]

In outpatient care

Molnar *et al*. stated that a speech recognition system can be an acceptable replacement for a manual system in outpatient care. They found that time spent on preparation and editing of reports provided by speech-to-text conversion technology was about 54 seconds (approximately 15%) more than manual documentation. However, it led to a significant reduction (over 5 days) in the overall time to complete a report.[33] Issenman *et al.* found that speech-to-text conversion technology reduced the duration of a patient visit in the outpatient from 9 to 3 minutes.[34] The speech recognition system is not only a promising system but also a useful and economic clinical tool[33] that reduces healthcare costs.[34] Although editing and recording of information takes longer time, the system significantly reduces delays in reporting as well as costs in documentation.[35] Molnar *et al*. believe that the speech recognition technology will be an integrated part of endoscopy laboratories in the future.[33]

In the emergency department

Speech-to-text conversion technology makes reports available seven times faster than when reports are recorded by traditional methods. This technology has a decreased turnover time and reduces the emergency report completion time from 12 hours and 33 minutes to 2 hours and 13 minutes while legibility showed a slight difference in both (recorded by speech recognition system and manual registration).[36]

Reports provided by traditional recording system are usually illegible and incomplete, which makes them inappropriate in legal cases. Moreover, writing records manually is expensive and needs more time. Given these problems and with the emergence of speech recognition software, it is possible to document accurately, quickly, in a legible form and with lower costs. The average cost for doctors' time was US$ 3.65 with a voice recognition system and US$ 3.77 with copying services. While this saving in terms of an individual doctor may not seem substantial, overall US$ 110 (equal to 22%) will be saved by using this technology. An advantage of this software is the ability to create a computerized patient file which can be used for statistical purposes. In 1989, a software was used in an emergency department of a big hospital to create text through controlling speech in a microcomputer. It was found that a speech recognition system lets doctors provide more accurate data in less time compared to hand dictation.[37]

Accurate clinical documentation is necessary in emergency services to enhance quality of patient care and for legal issues. For emergency, pre-hospital care, future wireless technologies could be provided. Wireless connection between microphone and computer inside an emergency centre can be valuable in such cases.[38]

TABLE I. Pros and cons of speech-to-text technology

Advantages	Challenges
• Reduction in cost and time in documenting information	• Acceptance by doctors and other healthcare providers
• On-line registration (coordination of activity and documentation)	• Initial cost of implementation and maintenance of technology
• Quick access to documents	• Variety of accents
• Improved and time-saving workflow in provision of healthcare services	• Unfamiliar with rules of grammer
• Accurate and legible information (about 99%)	• User training
• Reduction in patients' duration of hospital stay	• Hardware requirement
	• Sound pollution (noise)

In nursing assistance

Speech-to-text conversion technology offers EHR which needs innovative strategies for storage and saves nurses' time for looking after patients. According to studies, speech-to-text conversion technology increases productivity of nurses. However, this technology is accompanied by some concerns. It has been found that nurses prefer to enter data in EHR using a keyboard. Therefore, successful acceptance of this technology depends on respecting nurses' opinion, understanding the benefits that they perceive, training them, and minimizing barriers to software use.[39,40]

IMPLEMENTATION OF SPEECH-TO-TEXT TECHNOLOGY

This technology has some pros and cons (Table I).[31–40] Errors that occur when typing using speech recognition are subtle and need careful editing. Increasing system intelligence in correction is considered a negative consequence and is not a good factor for clinical documentation. Derman *et al.* found that a speech recognition system did not significantly improve workflow compared to conventional methods of data input or typing.[2] Before the study it was believed that a computer was always available to record electronic disease progress; however, after the study many participants suggested that speech recognition was not always available and this problem could lead to a delay in data input. They stated that they typed material during an interview with a patient and completed the form later, but with the new system they had to take all the notes after the interview with patients. Since they could not dictate in front of patients, they faced some problems. Eventually, staff with high workload claimed that the system was not appropriate for workflow management in hospital wards due to environmental noise and limited access to computers during an interview.[2] Despite the optimism with speech-to-text technology, there is no report of its successful integration in clinical wards.[41]

Working with discrete speech recognizer systems is awkward, time-consuming and user-unfriendly. Hence, until these problems are solved, continuous voice recognition systems are likely to continue to fail.[42]

CONCLUSION

Modern health information technologies such as speech-to-text systems improve quality and effectiveness of documentation of

health information. Equipping hospitals and doctors with an automatic documentation system will facilitate their work and increase the speed of treatment by healthcare providers, which will eventually address patients' expectations. Numerous factors should be considered when using this technology, some of which are: ease of software use, user's comfort with the microphone system, costs involved, acceptance by the healthcare team, especially doctors, and environmental requirements for sound recording such as noise or sound pollution. The use of this technology is expected to increase from 2006 to 2016 by 14%. Identification of advantages and challenges will help mechanize documentation of health information to a high quality.

More studies are needed to identify user characteristics and improve the acceptance of technology. It is expected that speech recognition algorithms and clinical vocabulary will improve in the future, so that natural languages can be understood by speech recognition systems. This way, dictation will come into a structured reality.

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