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Case report

Wearable technology leading to timely diagnosis and surgical management of spontaneous pneumothorax

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Abstract: Wearable technology (such as smart phones, watches, and rings) has become widely adopted, allowing patients to monitor symptoms and vital signs from homes. However, the implementation of these devices in clinical settings remains limited. Here, we presented a case demonstrating the role of wearable technology in the timely detection and management of primary pneumothorax, which required surgical intervention. This case illustrates wearable technology's potential for early detection of surgical complications through continuous physiological monitoring. The discussion includes the current implementation of wearable technology in the healthcare environment, as well as challenges and opportunities for advancement.

Keywords: Wearable technology, Thoracic surgery, Surgical decision making, Digital health, Early disease detection

Introduction

There is a growing trend in the use of wearable technology and its role in diagnosing surgical disease, as demonstrated in our case example. There has been an increasing demand for patients to access information and have agency of their own healthcare and personal electronic health records. The ONC's Cures Act Final Rule, signed in 2021, allowed patients to get more direct and real-time access to their electronic health records, with the goal of making health care more "affordable, personalized, and putting patients in control" [1]. The consumer market has observed this need and aimed to fill the gap by marketing wearable technology that provides consumers unfiltered and immediate access to their healthcare data. As of 2023, over 35% of US adults use wearable healthcare technology [2]. The rise of wearable technology has revolutionized how patients interact with their own health information, but to-date, the risks and benefits are poorly defined. In our case example, the patient had a wearable smart ring that typically captures physiological data (i.e. heart rate and variability, body temperature, movement, sleep phases, activity level, and blood oxygen rate). New-onset tachycardia suggests a wide differential diagnosis, including but not limited to spontaneous pneumothorax, which prompted immediate health care evaluation.

Current wearable technology devices have been

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modeled from the current market of home health devices. Diabetes glucose monitoring has been a longstanding example of wearable technology for patients, including 2.4 million continuous glucose monitors used in the United States today [3]. Home blood pressure monitoring has been available for decades, with Bluetooth and app-integrated devices appearing as early as the 2000s [4]. Today, new devices have been adapted to take validated blood pressure readings via wristwatch, providing real-time data [5]. Currently, the benefits of wearable technology are individualized depending on the indication (athletic performance, sleep training, etc). Physician assessment of wearable technology data has also begun to be explored as more patients use this information and share it with their health care providers as part of their personal health record. Here, we aim to demonstrate that wearable technology plays a role in detecting cardiothoracic surgical disease and surgical complications, using our case example and a literature review, while there remain several barriers to implementation across health systems.

The role of wearable technology in detecting cardiothoracic surgical disease

Cardiothoracic surgery is an area with significant potential for the expansion of wearable technology. Currently, wearable technology available to consumers and patients spans multiple organ systems, including cardiothoracic. Most wearable devices have the capability to interface with smartphone applications, store long-term data, and may provide prognostic value based on activity performance, along with on their data trends (Figure 1).

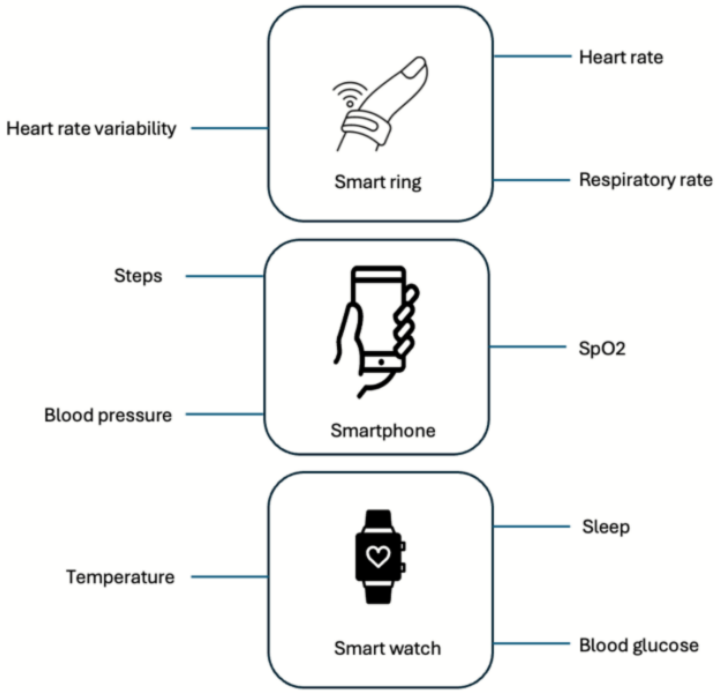

Figure 1. Implemented wearable technology across multiple platforms and a variety of physiological data points measured

Patients are often discharged from the hospital with a Holter monitor after being diagnosed with an arrhythmia, such as atrial fibrillation, for further remote monitoring. The use of photoplethysmography offers an opportunity to replace these devices, as it allows consumer smartwatches and rings to capture pulse rate as well as oxygen saturation. Trials by major smartwatch manufacturers in populations exceeding 400,000 individuals demonstrated that smartwatches could detect arrhythmias consistent with atrial fibrillation, with subsequent EKG confirmation rates of 84% for Apple and 98% for Fitbit [6,7]. Atrial fibrillation is one of the most common postoperative complications following cardiothoracic surgery, with an incidence of 35%, and can prolong hospital stay by an

additional 2 to 5 days [8]. Detection becomes beneficial in these patients due to the elevated stroke risk. Wearable technology devices may help reduce hospital costs through an inexpensive, and patient-facing postoperative monitoring process that patients can routinely use at home while providers track their progress remotely.

Surgical complication detection

Some of the earliest signs of postoperative complications include tachycardia, arrhythmia, tachypnea, or abnormal T wave spikes. A study from Massachusetts General Brigham involving 56 patients undergoing major cardiothoracic operations found that machine-learning analysis of high-resolution biometric data passively collected by wearable devices could detect 81% of postoperative events, most of which were major postoperative complications [9]. The researchers used a platform originally designed for early detection of COVID-19 and applied it to identify postoperative complications after cardiothoracic surgery. While wearable technology does not prevent complications, early detection may allow for timely intervention and improved postoperative surveillance. Expectations of surgery have changed over time, with greater emphasis on expedited pathways to recovery and discharge. Increasing postoperative monitoring after discharge may provide benefits, but this has yet to be rigorously tested.

Wearable technology has also been shown to be useful in tracking patient activity levels. Monitoring the activity levels of patients has been shown to be useful in predicting length of hospital stay and higher 30-day readmission rates [10]. Early mobilization is critical for postoperative patients, as it reduces the risk of deep vein thrombosis, pneumonia, and deconditioning. Monitoring patients activity after surgery and as they go home can emphasize early mobilization and may allow for early detection of a patient's decline. Several institutions focusing on "surgical readiness" through prehabilitation, including our own Michigan Surgical & Health Optimization Program [11], may benefit from incorporating wearables as an objective tool for assessing patient optimization prior to surgery.

Activity levels have also been found to be associated with mental health outcomes, as one study utilized a wristwatch to monitor activity levels in patients diagnosed with depression as an assessment of their response to SSRIs [12]. While this study aimed to demonstrate the benefits of physical activity for mental health, there may also be additional negative psychological impacts from continuous health monitoring. Physicians must consider the ethical impacts these devices may have on patients, such as increased anxiety and reliance on the devices for patients

Case description

A 24-year-old female presented to the emergency department with right-sided chest pain and shortness of breath that was exacerbated by lying flat. She reported that her wearable health ring (Oura Ring, Oulu, Finland) [13] notified that her heart rate, measured via photoplethysmography, was over 130 beats per minute, despite her baseline average heart rate being 60 bpm. She had no laboratory abnormalities. On physical examination, she was afebrile and tachycardic but otherwise hemodynamically stable and normoxic on room air. Her exam was notable for right- sided chest pain. Her chest x-ray showed a large right pneumothorax measuring 55 mm between the lung apex and chest wall. An urgent tube thoracostomy was performed, resulting in resolution of her symptoms, tachycardia, and pneumothorax on CXR. Her clinical condition improved, and the chest tube was removed 24 hours after insertion. Despite this trend, the right pneumothorax did not resolve completely, and a tube thoracostomy was performed again. At this point in her care, the risks and benefits of a right thoracoscopic apical blebectomy, pleurectomy, and mechanical pleurodesis were discussed with the patient, since she had failed first-line treatment for spontaneous pneumothorax and has an active lifestyle. The operation included a parietal pleurectomy, resection of the apical bleb in the right upper lobe, and mechanical pleurodesis of the diaphragm and lower portion of the parietal pleura. She tolerated the operation without complication and was transferred to the general care floor. Her chest tubes were removed on postoperative day 3 and 4, and she was discharged home.

Discussion

There are several challenges to the adoption of wearable technology in the clinical environment. Public safety as it pertains to healthcare data protection and broadening the interface between wearable tech data and the electronic medical record. A Pew Research Center survey found that 35% of smartwatch users considered sharing their health data with medical researchers to be an unacceptable practice, despite studying the link between exercise and heart disease [14].

Wearable technology can seamlessly transition from in-hospital to at-home use, offering many benefits for early detection and intervention. However, if a complication is diagnosed and patients are notified, the individual patient response will remain highly variable, as they are not within the controlled environment of the healthcare system. Physicians' access to wearable technology data remains inconsistent, and while in our example a smart ring detecting new-onset tachycardia prompted the patient to seek medical care, many patients may not pursue further evaluation for abnormal findings identified by their devices. Variability in patient responses to device-generated alerts, coupled with limited and non-standardized physician access to wearable data,

contributes to an unclear and fragmented pathway for the integration of wearable technology into routine clinical workflows. Clearer guidance on data interpretation, communication, and escalation thresholds will be necessary to translate wearable-derived signals into timely and actionable clinical care.

Another challenge to clinical adoption is the use of resources, including patient and hospital burden. Patients undergo extensive surgeries and spend days to weeks in hospital, often experiencing post-operative anxiety at discharge. Wearable technology may help mitigate some of these fears by providing an additional source of information and data. However, this access to data may increase the risk of technology dependency, heightened postoperative anxiety, and over-utilization of healthcare resources. Indeed, research studies have shown that patients were newly diagnosed with type 2 diabetes who used self-monitoring of blood glucose experienced no improvement in glycemic control, but close self-monitoring was associated with higher depression scores [15].

Finally, wearable technology may exacerbate disparities within healthcare. At the time of this publication, there is no reimbursement model or insurance coverage for these devices. Disparities have been shown in the pediatric type 1 diabetes population, in whom lower socioeconomic classes have lower technology use and higher HbA_{1c} levels [16]. There have also been concerns regarding the accuracy of pulse oximetry readings, which may apply to wearable technology, as these devices were not developed and tested on diverse populations and may not be accurate for individuals with darker skin pigmentation, potentially resulting in inaccurately high readings [17]. This may further exacerbate the existing inequalities in the health care system.

Conclusion

This case demonstrates the potential role of wearable technology in the timely detection of emergent medical and surgical diseases and postoperative complications. In our case example, a smart ring detecting tachycardia prompted a patient to present to the emergency department for her spontaneous pneumothorax, leading to prompt surgical intervention. Several key areas warrant further investigation. There is a need for additional prospective validity studies to assess the sensitivity and specificity of wearables across various demographics. Developing integration pathways between wearable technology data and electronic health records will enable physicians to be alerted to changes in patient wearable data. There will be an ongoing need for institutional and government regulation (FDA clearance) for the integration of wearable technology data into the electronic health record, and there is a risk of physician alert fatigue as more data become available. Practically, integration into clinician workflows is a concern, and artificial intelligence has a role in consolidating continuous data and optimizing existing wearable platforms to differentiate normal postoperative changes from true complications.

More importantly, there is a need to address equity concerns that may be exacerbated with wide adoption of wearable technology in clinical settings. Validation studies of pulse oximeters and many medical devices, including wearable technology, lack diversity, which could worsen rather than improve health outcomes for underrepresented populations. Careful consideration of implementing wearable technology with consideration of cost, access, and the direct impact of the "digital divide" on diverse populations, is critical.

Wearable technology, including smart rings, has demonstrated promise in detecting vital sign abnormalities, and its implementation within healthcare has expanded as studies have shown the ability to identify arrhythmias and postoperative complications in the outpatient setting. Patients and providers may have access to real-time data similar to an in-hospital experience, while the patient's physiology is monitored as an outpatient.

Although this case report is limited to a single-patient experience and descriptive data from the literature review, we believe we have demonstrated that wearable technology has potential for early detection of surgical complications. While barriers to implementing wearable technology in everyday clinical practice remain, we believe there will be growing utilization as the consumer market continues to develop and the health care system adapts.

Authors' contributions

D.C and C.E contributed to the design and implementation of the research, to the writing and editing of the manuscript.

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Competing interests

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Ethics

Patient consent was obtained prior to publication.

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