

Undergraduate Thesis Prospectus

Improving the Accessibility and Ease of Use of the Standard Ventilator
(technical research project in Biomedical Engineering)

Mitigation of Work-Related Mental Health Stresses Faced by Medical
Professionals
(sociotechnical research project)

by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem

How may healthcare provision be improved?

For decades, many have felt that the United States has done poorly at the just and fair delivery of health care, and over 50% of Americans, on average, have agreed that fundamental changes in regards to cost, accessibility, and quality of care are needed to improve the functioning of the healthcare system (LiPuma & Robichaud, 2020; Blendon et al., 2006). This common dissatisfaction with healthcare provision can be attributed to reasons including a lack of integration across and within healthcare sectors and organizations, workforce shortages and discontent among health professionals, and poor accommodation of patients' needs, especially of those belonging to underserved or marginalized demographic groups (Summit et al., 2003). Moreover, according to the U.S. Census Bureau's Survey of Income and Program Participation from 2018, 19% of households in 2017 were unable to fully pay for their medical services, and the issue of medical debt and inaccessibility disproportionately affected households of certain races and regions in the country, which still holds today (Bennett et al., 2021). While the U.S. government has continually tried to establish national policies for systemic reform and hospitals have attempted to alter their methods of operation to improve the quality of care for both patients and providers, the delivery and accessibility of care continues to be strained by the effects of the COVID-19 pandemic, and more than ever, it is crucial that the underlying causes of the poor healthcare provision are studied and improved upon to ensure the health and wellbeing of the public (Grimm, 2021).

Improving the Accessibility and Ease of Use of the Standard Ventilator

How may Ventis Medical improve the accessibility and ease of use of its low-cost emergency ventilator for medical professionals and their patients?

In 2018, up to 20 million people were dependent on admission to Intensive Care Units and mechanical ventilation in order to breathe, and this number has since increased due to the COVID-19 pandemic (Ambrosino & Vitacca, 2018; Tsai et al., 2022). Despite this high demand, ventilators tend to be expensive, costing \$30,000 to \$50,000 on average; heavy, usually weighing 7-18 pounds; difficult to use without extensive training; and overall inaccessible (UCLA Health, n.d.; Your ALS Guide, n.d.). This especially became a problem when the pandemic hit, during which there were shortages in ventilator supplies and trained staff. In the absence of ventilators, bag valve devices (BVDs) are used, which require the operator to manually squeeze air every 5 seconds (Merck, 2022). Due to a lack of built-in controls and patient feedback, it can be easy to deliver incorrect ventilation through this method.

Ventis Medical seeks to improve emergency ventilation and patient care by reducing expertise and training barriers that are currently present in ventilation delivery with its low-cost emergency ventilator, the VM-2000. As compared to the standard ventilator, the VM-2000 is available at a much lower cost and features improved efficiency, ease of use, and portability, making it better suited for emergency situations. Currently, the VM-2000 requires each of its 6 cables to be plugged into its own connection port, features a tubing length of 1.8 meters, and has a ventilation function that is enabled by a button on the main body of the device. However, this may prolong the assembly of the device, cause tubing entanglement, and delay the delivery of patient care. Thus, the goal of this project is to improve the design of the VM-2000, specifically the ease of use of the tubing configuration and the incorporation of a remote ventilator access device (RAVD), allowing ventilation to be more conveniently and efficiently enabled by the caregiver.

This overarching goal can be divided into the subgoals of (1) shortening the tubing to lengths that are more suitable and favorable for emergency situations, (2) using Fusion 360 to design a 3D-printed manifold to allow for simultaneous connection of the tubing components to the main body of the device and a 3D-printed sleeve to contain all of the tubing and cable components for optimal organization, and (3) integrating a Bluetooth-connected button to enable wireless administration of automated ventilation. This Capstone project in Biomedical Engineering will be advised by Timothy E. Allen, and project collaborators other than myself include Christian Anton and Casey Ma.

The aims of the project will be employed by first researching the limitations of current ventilation techniques and mechanisms while also surveying emergency responders and health professionals on the user friendliness of current models. We will account for this information in addition to human factors perspectives as we make design choices for the tubing length, 3D printed prototypes for the manifolds and tubing sleeve, and RAVD; ask emergency responders and medical professionals to test and provide feedback on the ease of use of our novel designs; and iterate the prototyping-testing process until a finalized, optimal configuration is reached for all components. Constraints under which we will be working include that the current types of tubing attachments and connection ports of the VM-2000 must not be altered and that the Bluetooth-enabled RAVD must be able to integrate into the existing software of the VM-2000.

Our work intends to set a precedent for the functionality of portable ventilators by optimizing device utility and efficiency of patient care. The success of this project would result in the simplification of ventilator usability, including an improved organizational system of ventilator tubing and wirelessly-enabled ventilation administration. With the advancement of the VM-2000, this project can reduce the amount of manpower and expertise needed to provide

quality care to patients, improving the ease of ventilation administration for both patients and caregivers, and ventilator treatments can thus be more broadly used across different facilities and situations.

Mitigation of Work-Related Mental Health Stresses Faced by Medical Professionals

In the U.S., how are hospitals, clinics, professional societies, and physicians seeking to mitigate the work-related mental health stresses to which medical professionals are subject?

Mental health conditions such as depression and burnout occur at inflated rates within the medical profession, which have negative implications on both the personal lives of health professionals and the quality of patient care they provide (Tackett, 2018). The severity of these issues and their effects has exacerbated because of the COVID-19 pandemic, making this an urgent public health priority to be addressed (Søvold et al., 2021).

Researchers have examined causes of poor mental health within the medical profession as well as proposed solutions to the problem. Tackett (2018) suggested that increased workload and hours, escalated public expectations, and sense of duty to patients have contributed to a decline in the mental well-being of healthcare providers and proposed that decreasing the stigma around illness in general may improve the crisis. Spoorthy et al. (2020) found that healthcare workers are more prone to developing adverse psychiatric symptoms, especially in light of the pandemic, and that risk factors include insufficient support, training, and communication and maladaptive coping methods. Norman et al. (2020) surveyed frontline healthcare workers at Mount Sinai Hospital in New York City during the height of the spring COVID surge in 2020 and found that moral distress, in the forms of family-, infection-, and work-related concerns, plagued the majority of the sample, which corresponded to COVID-related PTSD symptoms, burnout, and

work and interpersonal struggles. The results of this study suggested that the assessment, prevention or mitigation, and early intervention of moral distress can mitigate the mental health conditions that permeate the medical profession. Søvold et al. (2021) elaborated on the acceleration of these mental health challenges due to the pandemic and emphasized the importance of support resources, global collaboration, and changes in workplace culture and policy in addressing the needs of healthcare workers.

Participant groups advocating for the mental health of medical professionals include the American Medical Association (AMA), National Alliance on Mental Illness (NAMI), Mental Health America (MHA), and Mental Health First Aid. The AMA pushes for changes in legislative, regulatory, and health systems in support of the mental health of medical students, residents, and physicians (AMA, n.d.). NAMI speaks to medical professionals, stating, “You already know that it’s important to take care of yourself physically, and in order to serve safely and effectively, it’s just as important to take care of your mental health” (NAMI, n.d.). MHA strives to assist professionals in the field by providing “resources to help healthcare workers cope with the mental health impact of their work” (MHA, n.d.). Mental Health First Aid also provides resources to reorient the attitude surrounding mental health within the medical profession (Hoffman, 2017).

While the prevalence and severity of these mental health conditions have been recognized by both researchers and advocacy groups, many medical professionals, comprising an additional participant group, feel as though these issues still have not been addressed adequately. An NPR health correspondent spoke for many healthcare workers in an interview, expressing that “frontline providers feel like their concerns, their mental health issues are being dismissed by those in positions of power in their industry and society at large” (Chatterjee, 2022). Despite the

government's efforts in addressing the problem in ways such as sending pandemic relief money to providers or grant money to researchers and hospital systems to fund mental health care for their employees, many medical professionals believe that "it's really lawmakers and health care systems that really have to take this up seriously and address those underlying causes - underlying systemic causes of stress like the staffing shortages" (Chatterjee, 2022). Nurses in particular have felt that their mental health has in fact exacerbated since the pandemic although more resources had been implemented, in theory, to support staff wellbeing. In a survey conducted by *Nursing Times* to assess the mental health of nurses one year into the pandemic, one nurse had testified, "We are constantly told we need to have a rest, get support, relax, take a break away from everything – and yet there is no time set aside for us to do just that" (Ford, 2021).

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