# Opportunities to Support Mechanical Ventilation Weaning

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Individuals with spinal cord injury or disorder (SCI/D) may experience respiratory impairment and require mechanical ventilation. A key clinical goal is to withdraw ventilator support when possible to manage the risk of secondary complications. However, mechanical ventilation weaning (MVW) trials are often a stressful experience since feelings of inability to breathe and failed weaning attempts can induce anxiety. This study aims to support patients' more comfortable and theoretically expedited MVW process. Our findings reveal the potential for technology integration to support MVW and key challenges for implementing various technologies. Considering the design and implementation barriers within the clinical context is vital as we move toward such technology-oriented solutions.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**.

Additional Key Words and Phrases: Spinal cord injury; mechanical ventilation weaning; virtual/augmented reality

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## 1 INTRODUCTION AND BACKGROUND

Spinal cord injury and disorder (SCI/D) occurs from damage to the spinal cord that results in persistent changes in sensation, muscle strength, and other motor and bodily functions, including respiration. Individuals with SCI/D often experience respiratory system impairment in the acute rehabilitation phase — and some experience longitudinal respiratory changes [4]. As a result, approximately two-thirds of patients with acute SCI/D require mechanical ventilation (MV) [1]. MV is a process of providing external respiratory support with machines to help patients who cannot breathe on their own. While critical to patient care, the longer the duration of ventilation, the higher the risk of multiple secondary complications, including ventilator-associated infections and atrophy of muscles of respiration [12]. MV limits communication and full participation in rehabilitation therapies [6, 8] and research [7]. Accordingly, withdrawing MV support at the proper time is critical.

The process of promoting independent breathing and withdrawing ventilator support is called mechanical ventilation weaning (MVW) [12]. There are several physiological and psychological barriers to expediting the process of MVW [3]. Physiological barriers are generally related to diminished respiratory muscle strength [2] while psychological barriers to MVW include anxiety, fear, and distress [11]. MVW is stressful because it requires individuals to attempt breathing without mechanical assistance after they have been reliant on ventilation support for a while. This problem highlights a space to improve respiratory therapies, wherein health care providers (HCP) could augment current practices using technological innovation and integration. Past work on patients' experiences during MVW described some important experiences, including frustration, uncertainty, hopelessness, fear, and lack of mastery [5]. Some studies suggested how HCPs might use technology to assist with the MVW process, for example, by computerized weaning protocols [10]; however, the technology was HCP-focused. There has not been any prior work exploring technologies that help the patient through the MVW process.

This study is a combined effort of researchers from physical medicine and rehabilitation and computer science — specifically, investigators with backgrounds in rehabilitation psychology and human-computer interaction (HCI). Together we examined opportunities to support a more comfortable and faster weaning process for patients with SCI/D. Through this work, we aim to provide a more in-depth insight into the patients' and HCPs' experiences and to provide design guidelines for technology-based solutions supporting MVW.

## 2 METHOD

We conducted semi-structured interviews with four HCPs (P1-P4) at the University of Utah rehabilitation hospital with questions about the challenges of the MVW process, the role of current technology in supporting patients, and possible challenges for those technologies. We conducted a thematic analysis of the interviews and identified ten high-level themes. We then used these themes to draw important implications for the design of technology that might help support the patients and the HCPs during MVW. Based on their responses, and with approval (IRB_00121564) from our institutional review board, we also tried a few technology-oriented methods for coping with the anxiety of MVW with one spinal cord injury (SCI) patient. We observed his reactions as a case study.

## 3 FINDINGS AND CASE STUDY

All HCPs interviewed mentioned anxiety as the biggest challenge for patients during MVW: *"I think the biggest barrier is anxiety." (P3)*, and it's a justifiably fearful patient experience. They mentioned some important considerations for designing technology to support MVW. First, communication is a critical factor. Since the patients already have limited control, they may struggle with tolerating anything that feels restrictive to their communication. Any technological solution needs to ensure that the patients can still communicate. For example, if the patient can only communicate through blinking, their eyes must be visible to the HCP. This finding affects how we might use virtual reality (VR) or augmented reality (AR) technology for MVW. Second, technology-based solutions should address anxiety-inducing factors and help the patients relax to tolerate MVW better. HCPs suggested highly-immersive and interactive content to make the experience more engaging, potentially through images, videos, or games presented on a traditional or mobile display or VR/AR headsets.

The HCPs also indicated that some adverse events might arise for particular technologies. For example, there are specific concerns with VR headsets themselves: VR's limited capability of being used in a reclined position, increased stress while wearing the headset, the VR headset being yet another device on the patient, and the VR headset blocking the field of vision — which may lead to claustrophobia. Additionally, the central idea for reducing anxiety is to distract the patient and minimize the impact of the anxiety-inducing factors; however, the HCPs indicated that it might be challenging to distract some patients due to their medical condition. Lastly, it is essential to consider barriers to implementation that affect HCPs as well, such as adding many extra tasks to an already stressful and busy schedule.

The HCPs also suggested that: 1) a wireless technology setup could help reduce restrictive feelings and associated stress for the patients, 2) designing a more interactive system could enhance patient engagement, 3) include a way to control what the patient sees at all times, and 4) quick and easy system setup for HCPs to maximize their limited time.

Based on the initial findings, we tried two methods to support an SCI patient (21-year-old male) at the university rehabilitation hospital to cope with the MVW stress and observed his reactions. First, P2 showed a relaxing video on a phone screen for 15 minutes during an initial MVW trial. During this trial, the patient showed no signs of distress; rather, he was calmer. After concluding the trial, the patient felt he could not have completed it without the help of the video. The video trial had some drawbacks: the HCP became tired from holding the phone for the patient, and the patient experience was passive rather than immersive.

Second, we proposed that the patient could use a VR headset for the next trial. The caregiver of the patient informed us that the patient had used VR headsets before the injury without complications. He also expressed interest in using it; however, immediately after putting it on, the patient signaled the HCP to take it off. The patient indicated that he felt claustrophobic with the headset on because he could not speak or take the device off by himself. Additionally, he could not see his surroundings with the headset occluding his eyes, thus inducing stress rather than alleviating it. This trial reconfirmed the necessity of a communication channel between the patient and the HCP, especially for VR headsets.

## 4 DISCUSSION AND CONCLUSION

Expediting MVW may reduce the risk of complications. This study investigates opportunities for technology to support MVW and identifies some important issues that must be addressed while designing technology-based solutions for this purpose. These observations highlight areas where technology can better support more comfortable MVW. Based on this analysis, we suggest the following design guidelines for such technologies.

First, prioritize patients' ability to communicate with HCPs during the experience: If any design occludes the eyes of the patient, this will limit the patient's ability to communicate. Therefore, the design of any technology-based solution must incorporate alternative communication methods for the patient. Second, balance the risk of additional stress and the positive impact of immersive experiences for the patient. If patients are captivated by a stimulus taking most of their conscious attention, fewer cognitive resources will be available for the anxiety-provoking stimulus. Therefore, patients will subjectively experience reduced stress [9]. Third, consider the needs and burdens of the HCPs. Even though the primary goal of technology integration is to help reduce patient anxiety, healthcare providers will also interact with the system. Thus, the design of such a system would need to consider the needs of the HCPs as well.

One promising solution is AR. HCPs indicated, and as we found in our case study, VR involves the risk of claustrophobia and other similar adverse situations. Transparent AR glasses may address many of the concerns noted in this study. HCPs would be able to see the eyes of the patients to identify stress, and patients would be able to see their surroundings. AR might reduce the risk of claustrophobia while providing an engaging patient experience.

We call for the Ubicomp community to explore other effective designs and implementations to support MVW.

## REFERENCES


[1] Robert Brown, Anthony F DiMarco, Jeannette D Hoit, and Eric Garshick. 2006. Respiratory dysfunction and management in spinal cord injury. *Respiratory care* 51, 8 (2006), 853–870.

[2] Jean Chastre and Jean-Yves Fagon. 2002. Ventilator-associated pneumonia. *American journal of respiratory and critical care medicine* 165, 7 (2002), 867–903. https://doi.org/10.1164/ajrccm.165.7.2105078

[3] Yu-Ju Chen, W Jake Jacobs, Stuart F Quan, Aurelio J Figueredo, and Amy HT Davis. 2011. Psychophysiological determinants of repeated ventilator weaning failure: an explanatory model. *American Journal of Critical Care* 20, 4 (2011), 292–302. https://doi.org/10.4037/ajcc2011886

[4] Mayo Clinic. 2019. Spinal Cord Injury- Overview. https://www.mayoclinic.org/diseases-conditions/spinal-cord-injury/symptoms-causes/syc-20377890, Retrieved: 25 November, 2019.

[5] Deborah J Cook, Maureen O Meade, and Anne G Perry. 2001. Qualitative studies on the patient's experience of weaning from mechanical ventilation. *Chest* 120, 6 (2001), 469S–473S. https://doi.org/10.1378/chest.120.6_suppl.469S

[6] Sarah E Jolley, Christopher R Dale, and Catherine L Hough. 2015. Hospital-level factors associated with report of physical activity in patients on mechanical ventilation across Washington State. *Annals of the American Thoracic Society* 12, 2 (2015), 209–215. https://doi.org/10.1513/AnnalsATS.201410-480OC

[7] Kazi Sinthia Kabir, Ahmad Alsaleem, and Jason Wiese. 2021. The Impact of Spinal Cord Injury on Participation in Human-Centered Research. In *Designing Interactive Systems Conference 2021* (Virtual Event, USA) *(DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1902–1914. https://doi.org/10.1145/3461778.3462122

[8] Rabia Khalaila, Wajdi Zbidat, Kabaha Anwar, Abed Bayya, David M Linton, and Sigal Sviri. 2011. Communication difficulties and psychoemotional distress in patients receiving mechanical ventilation. *American Journal of Critical Care* 20, 6 (2011), 470–479. https://doi.org/10.4037/ajcc2011989

[9] Kevin D McCaul and James M Malott. 1984. Distraction and coping with pain. *Psychological bulletin* 95, 3 (1984), 516.

[10] Sahiti Myneni, Debra McGinnis, Khalid Almoosa, Trevor Cohen, Bela Patel, and Vimla L Patel. 2016. Effective use of clinical decision support in critical care: Using risk assessment framework for evaluation of a computerized weaning protocol. In *Advances in Healthcare Informatics and Analytics*. Springer International Publishing, Cham, 217–232. https://doi.org/10.1007/978-3-319-23294-2_10

[11] Armando J Rotondi, Lakshmipathi Chelluri, Carl Sirio, Aaron Mendelsohn, Richard Schulz, Steven Belle, Kelly Im, Michael Donahoe, and Michael R Pinsky. 2002. Patients' recollections of stressful experiences while receiving prolonged mechanical ventilation in an intensive care unit. *Critical care medicine* 30, 4 (2002), 746–752.

[12] Hossam Zein, Alireza Baratloo, Ahmed Negida, and Saeed Safari. 2016. Ventilator weaning and spontaneous breathing trials; an educational review. *Emergency* 4, 2 (2016), 65.