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Part 3

Ventilators, Ventilators, Ventilators

David Hawks
VP, Strategic Development

Bill Croisetiere
VP, Strategic Development

Ventilators have become synonymous with the current COVID-19 outbreak. As hospital demand skyrockets 11-fold due to the exponential increase in COVID-19 patients, supply chain and manufacturers have been stretched beyond capacity. Efforts to project ventilator demand in the U.S. range from 45,000 units to 75,000 units, with 880,000 units projected demand worldwide.

The U.S. recently announced orders for 137,431 new ventilators, worth $2.5 billion, delivered by the end of 2020. In order to meet this demand, a growing list of traditional and non-traditional medtech companies, as well as universities, investors, and entrepreneurs have pledged time and resources to the effort. Tesla is designing ventilators from Model 3 parts along with a partnership with Medtronic. General Motors plans to begin producing 10,000 ventilators per month by mid-April, and Ford hopes to produce 50,000 of the devices in the next 100 days.

Most commercial units from the ramp up will take months to reach patients. In the meantime, open sourced, rapid prototyped options are being explored. Medtronic has released full design and manufacturing specs for their portable ventilator (Puritan Bennett 560), and top university teams have released open source schematics of various designs (MIT, Georgia Tech, and Rice).

However, in the context of the current outbreak, ventilator demand in the U.S. is projected to peak by mid-April, with much of Europe already past peak demand, and developed Asian countries well beyond that point. J.P. Morgan analysts are predicting that the near future demand for ventilator and COVID-19 associated resources, will quickly move to developing countries. By most estimates, the demand in the developing world will far outpace what we have seen so far, but solutions implemented in the developed world will face challenges in low resource settings.

With the slew of ventilator designs that have been published in recent weeks, there is likely confusion as non-traditional Medtech manufacturers look to contribute to the COVID-19 efforts. To understand the challenges in bringing these technologies to hospitals, we spoke with Ximedica's Bill Croisetiere, VP Strategic Development, Manufacturing and David Hawks, VP Strategic Development, to understand risk and opportunities of ventilator design and production. We analyzed Medtronic's full featured ventilator platform, emerging solutions from entrepreneurs, and propose a set of requirements for a "just right" ventilator solution in our "call to action."

Do you believe the Medtronic plans that have been released are sufficient to manufacture the ventilator by someone new to the industry?

Bill C.: Yes, it is possible for someone new to the industry to take the information provided and develop a product branded as their own. The caution I would highlight is that this is a medical device and will require a certain rigor of regulatory oversight and supply chain capabilities as well as appropriate testing and verification to meet an intent for human use. Although the FDA has lessened the requirements to receive an EUA to help combat COVID-19 there are still very specific requirements that will need to be understood, controlled and met within an ISO 13485 compliant QMS. In addition, an EUA submission requires a legal brand owner and sponsor to accept the responsibilities of these products once they are released for use.

How long would it take to bring Medtronic's open sourced plans through review to manufacturing?

Bill C.: I believe that it would take a very focused effort of more than a few people months of engineering, regulatory and business activities to support the transition into manufacturing and commercial availability.

What are the key barriers?

Bill C.: The need for a brand owner, about $1 – 1.5M to invest and access to the medical device supply chain to procure components are a few... Additionally, some of the efforts are sourcing of components, tooling and custom parts. The identification of replacement components as needed and development of the manufacturing process within a facility with a valid ISO 13485 compliant QMS and the appropriate regulatory support are some of the first items that come to mind.

The BOM includes over 800 components before accessories and manufacturing fixtures. We would need to review the bill of materials (BOM) and source all of the parts. Once we understand the supply chain, we would determine the cost to manufacture one unit and then propose costs to manufacture it in various quantities.

Additionally, the current state of manufacturing and supply chain means we would need to determine if we can get a steady stream of supplies with the world in "shelter at home" mode and suppliers working in many cases against each other for the same components.

Dedicated contract manufacturing and design houses such as Ximedica have people full time devoted to supply chain management and they check for primary and secondary suppliers for all parts in their manufacturing process.

What can be done if a part is not available?

Bill C.: If some components are not currently available or goes EOL (End of Life), then a substitute part needs to be chosen. An engineering analysis needs to be performed to determine if it is equivalent or if it is different enough that it needs additional testing and verification. This testing could be functional testing, Metlabs, UL, or FCC testing.

Strategies to adapt the design for lower resourced settings or faster manufacturing ramp up?

Bill C.: If one is planning to take on such a project the best strategy, I would recommend is to not change anything you don't have to. Changes will cost time, money, resources and in many cases induce more problems. For faster ramp up to production, your early planning should consider and organize what is needed to be done, how it should be done, who should do it, and when it should be done in order to ramp-up production successfully.

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To address the acute shortage of ventilators, a number of entrepreneurial initiatives have looked to "DIY" mechanical ventilator designs that can be manufactured using rapid prototyping techniques and off-the-shelf materials, by basically compressing a CPRD bag using a programmable system like an Arduino board. The University of Minnesota and Rice University are examples of such entrepreneurial teams working on similar projects.

The DIY nature of these systems means that non-medical device companies with access to laser cutters, additive manufacturing systems, and simple tools can theoretically replicate these open sourced designs. However, questions and challenges around reliability, efficacy, and scalability must be addressed.

David Hawks, VP of Business Development at Ximedica highlights a few takeaways on how teams can successfully move rapid prototype designs closer to clinical setting.

What should be top of mind when engineering teams want to develop a viable solution to address the ventilator shortage with low-cost, rapid prototype solutions?
David H.: First and foremost, it is crucial to remember that ventilators can help patients but can also harm. Just having a bag and pushing on it mechanically is not enough. Programmable pressure sensors, volume sensors, alarms, and disposable components are necessary and non-trivial.

Also you have to remember that most gases, including oxygen, are delivered at 50 psi in the United States. Not all 3D printed valves and regulators are appropriate for high pressure applications and local gas delivery specifications need to be well understood.

What control design criteria are necessary for a minimal viable product?
David H.: Two control algorithms can be utilized (volume control vs pressure control). In both cases, medical staff needs to assign an inhale / exhale ratio. Bag designs are inherently volume controlled, so we need to account for different bag geometries to deliver a consistent volume.

There are also two breathing trigger mechanics commonly used (mandatory breathing vs spontaneous). Forced, mandatory breath is best suited for patients that have lost control over their breathing and make no inspiratory efforts, therefore ventilator triggers and cycles the breath; spontaneous breath is likely to deliver better compliance and long term outcome but requires additional sensors to trigger inhalation and exhalation.

Finally, there needs to be programmability to account for patient BMI, while maintaining a minimal positive pressure is needed to prevent lung collapse.

How should teams think about the regulatory pathway for these rapid prototyped devices?
David H.: These systems are likely to raise regulatory concerns outside of the current emergency as possible bypassing the necessary controls that a medical device manufacturer would utilize (following cGMP's) could prevent them from becoming approved devices in the short/medium term. Device manufacturers should expect to follow up their emergency use authorization (EUA) with a 510(k) submission.

Where do we go from here?
With the global social distancing efforts, the first wave countries are seeing decreasing rates of new infection and hospital admissions and we are seeing important signals of where the pandemic progresses from here.

First, there are emerging reports that the SARS-CoV-2 virus has mutated into at least 3 distinct families and at least one strain found in India showed changes in how the virus targets human cells. These new complexities will confound the current progress on diagnostics and vaccine development efforts, likely extending the time frame of the pandemic, costing additional lives, and suppressing the global economy.

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Next, we are beginning to understand the burden of COVID-19 on hospital resources with hospitalization rates at 10.6% (vs flu of 1.33%) and median hospital stay of 12 days (vs flu of 3.6 days). There are also emerging reports of high mortality rates among intubated patients, with some reporting out of New York hospitals as high as 80%. It is clear we are in the early innings of understanding SARS-CoV-2 and COVID-19, the impact on human health, and best course of treatment. Flexibility and the ability to adapt new and existing equipment quickly will be key to an evolving care regiment for COVID-19 patients.

Finally, the virus is projected to have a devasting impact in South and Southeast Asian countries (India, Afghanistan, Pakistan) and African countries. A greater percentage of subsistence workers and day laborers along with insufficient government support means lower compliance with quarantine orders. This next wave of the pandemic could see a dramatic increase in numbers infected in a healthcare system very different from those in China, United States, and Europe.

As companies and teams around the world innovate to address the surge of demand of ventilators and diagnostic tests, there is an influx of stopgap designs by both frontline health workers and by entrepreneurial companies. It is important to remember patients (COVID-19 or otherwise) are very sick and require safe, effective, and reliable equipment that does not add to the burden of healthcare workers.

A CALL TO ACTION

The search for Goldilocks

Ideally, there is a functional compromise between a full featured ventilator and the DIY platforms highlighted in this article. A low cost, manufactured device, with necessary features for efficacy and safety, operated on a compressor, oxygen or air source, appropriate for emergency outbreaks or long-term care, depending on need.

Without the need for continuous power, this device would be an ideal backup ventilator for the management of difficult situations such as mass casualties, natural disasters, disease outbreaks, major power outages and solutions for transportation needs, whether in or out of the hospital. This interest place in the continuum of care, combined with the lower level of complexity of these devices from a design, usability and manufacturing perspective makes them an attractive option in certain marketplaces where the higher end systems are not an option.

Reach out and leverage our network and expertise to advance your design or product. We are actively working with multiple stakeholders, from manufacturers and investors, to university and hospital teams, to understand the specification and design of these types of “just right” systems.

Join the conversation today. Connect with David Hawks, VP Strategic Development (DHawks@ximedica.com) and Bill Croisetiere, VP Strategic Development, Manufacturing (wcroisetiere@ximedica.com) to find out more.

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