

Let's talk Ventilation

Graeme A'Court interviews Professor Ehab Daoud from John A Burns School Of Medicine (JABSOM) university of Hawaii, USA and currently serves as the president of the Society of Mechanical Ventilation.

Topic: Lung protective ventilation

Q1: Please tell me about how you developed an interest in this topic?

Answer: 25 years ago we only talked about barotrauma in the form of pneumothorax, then came the low tidal volume (6ml/kg IBW) and the shift towards volutrauma. The arguments continued to which is more harmful, the volume or the pressure and in my mind, it is both. Luckily over the last decade there have been more focus on Lung protective ventilation and VILI. Now we know that we must pay attention to all the parameters we set on the ventilator not only tidal volumes and driving pressures (PEEP, Flow, RR, Inspiratory time, FiO₂) as well as what is the patient is doing and the interaction between the patient and the ventilator and dyssynchronies.

I don't think we are there yet, and our knowledge will continue to improve, but for the mean time we need to do what we can to minimize lung injurious ventilation by personalized ventilation not one hat fits all (low tidal volume ventilation and PEEP-FiO₂ tables)

Q2: A: What are your thoughts on lung recruitment maneuvers and is there a place for them since the most recent publications have thrown some doubt on the overall benefit of them?

B: do you have these tools on the ventilators and are they used on a regular basis?

Answer: That is true, recruitment maneuvers have gotten bad rep from recent studies.

The benefit from a recruitment maneuver is to open collapsed alveoli but PEEP need to be adjusted to prevent their de-recruitment, on the other hand they can pose some hazards though most studies showed they are pretty safe in general.

I do not think that every patient with ARDS requires or would benefit from recruitment maneuvers. We must remember that not all ARDS lungs act similarly, depending on the etiology, the duration, some can be recruitable, and some might not be recruitable. The idea is to find the patients who might benefit from those maneuvers for example by looking to the quasi-static pressure-volume curve and look it the hysteresis at 20 cmH₂O pressure or if there is gain of volume with short 5 seconds pause at the end of the inspiratory curve.

I try to find the patient who might benefit from them and would do them if necessary but not every patient.

I do work with 2 different ventilators that have those tools that allow me to do those recruitment maneuvers and help me set the PEEP, driving pressures, tidal volumes in a safer way to prevent atelectotrauma and overdistention.

Q3: What are your thoughts of the use of driving pressure, mechanical power, pressure limitation, 6 ml/kg or adjusting the tidal volume based on compliance

Answer: As I mentioned above, I think that every parameter we set on the ventilator can potentially be injurious, as well as the patient-ventilator interaction too.

For the tidal volume, of course it makes sense that less tidal volume would be less injurious than bigger ones. Despite the evidence of the reduced mortality from the ARDS network trial in 2000, I have always criticized the study in many ways. First why do we call 6ml/Kg IBW low tidal volume though it is almost the normal tidal volume of a healthy person so in lung injury and reduced aeration, this is still high tidal volume and why did we compare it to enormously large tidal volumes 12 ml/kg IBW that I don't recall even using such volumes even before the study in the 90s. Secondly, the study had all kinds of ARDS from different etiologies, again not all ARDS are the same. Thirdly, setting PEEP per FiO₂ is way too simplistic, non-physiological, and in my opinion is the wrong way to do, however it gained much popularity just because it is simplistic. I never set the PEEP that way and always teach against the "one hat fits all approach" but always based on a "personalized ventilation strategy" however this is a much longer discussion.

Regarding the driving pressure (DP), there was a two-school debate of volumes or pressures, and which is the one contributes to VILI. Though I believe it is both and their contribution combined, but if I must then I'll put myself in the pressure school team. The reason is that the driving pressure is related to the respiratory system compliance and makes sense that the worst compliance like severe ARDS would require more DP and energy to inflate the lung compared to the more compliant system for example mild ARDS (though compliance is not included in the Berlin definition of ARDS).

The mechanical power is a major step forward in our understanding of VILI. Now for the first time, we acknowledge that it is not only the tidal volume or the driving pressure, but other factors that are obvious and I acknowledge that I didn't think of before. The inspiratory flow, the PEEP, the inspiratory time, the respiratory rate etc.

Saying this, I must emphasize that we are not there yet, there are still so many unknown issues and questions about the mechanical power.

First, which components of the power is more important (e.g. elastic vs resistive) (static vs dynamic). Second, is the mechanical power to the whole respiratory system (lung and chest wall) or the Transpulmonary mechanical power acting only on the lung (stress)? In my mind it is the transpulmonary power. Third, is it enough to measure and follow the power only or we should index it to the amount of injured lung (compliance/elastance, amount of aerated lung)? Some studies shows that the mechanical power or trans-pulmonary power did not correlate to mortality but indexing it did correlate with mortality.

Fourth, what about the patients' own inspiratory power, is it protective or additionally injurious, and how about the patient-ventilator asynchronies that happen to most patients during mechanical ventilation and their effect on the power measurements?

Fifth, we always assume passive expiration and concentrate on inspiratory power ignoring the expiratory phase which is not always true.

Sixth, is how do we calculate the mechanical power, there are multiple different complex and simplistic equations for different modes, and we need to unit those measurements, probably the best way to do it is through computing the pressure-volume curve directly. I do not see clinicians constantly calculating the mechanical power every time they make changes or every time the patient condition changes, it has to be monitored and displayed automatically by the ventilator. To my knowledge this is already in progress.

Q4: A: How do you set optimal PEEP and is this based on improving the PaO₂ or based on trying to have an open lung strategy?

B: do you have these tools on the ventilators and are they used on a regular basis?

Answer: Setting PEEP is one of the biggest challenges in mechanical ventilation, and after more than 50 years of research, we still cannot have a good answer.

The real problem is, both the normal and injured lungs are markedly heterogenous and each lung segment is under different stress and strain from the different forces inside and outside the alveoli based on its own mechanics not the oversimplistic approach of one compartment with one resistance and compliance. So one level of PEEP might cause overdistention and strain in some lung zones and under distention in other parts causing atelectrauma. Basically ideal PEEP does not exist. The effect of PEEP on the mechanical power is also matter of debate, whether it is kinetic energy stored and not contribute to the cyclical energy, its indirect effect on the compliance and thus the DP and TV is also variable depending on the recruitability of the lung.

However, I try to set the PEEP based on more physiologic data that I can get from the ventilator, for example I use the quasistatic pressure-volume curve as much as I can and look for all the information it gives me (low inflection, high inflection points, point of maximum curvature, hysteresis) to determine how to set it. Another approach is the decremental PEEP after a lung recruitment, if possible, to achieve the best compliance I can get trying to avoid over and under distention. Third which is my favorite, is the esophageal balloon manometry and I use it frequently but not in every ARDS patient, it allows me to set the PEEP above zero end expiratory transpulmonary pressures to prevent alveolar collapse from outside forces.

I have those tools on two state of the art ventilators and use them very frequently.

Q5: A: Thoughts on the use of using esophageal pressure monitoring as part of the lung protective strategy?

B: do you have these tools on the ventilators and are they used on a regular basis?

Answer: In my mind, the use of esophageal balloon is a must and should be a standard of care in mechanically ventilated patients. Depending on the airway pressures only is just looking at one side of a coin or my own analogy is looking at the better face of the “two faced villain” in the Batman comics.

The airway pressures tell us about the forces inside the alveoli, but how about the forces acting outside the alveoli? A balloon can be ruptured (VILI) from putting too much pressure inside (plateau pressures) or deflated with putting too much pressure outside (pleural pressure), so knowing the pleural pressures is extremely important to prevent VILI. It really surprises me how we never adopted such technology at the bedside, and it remains only as a lab tool, but I am confident it will be used more frequently in the future.

Knowing the end-inspiratory and end-expiratory transpulmonary pressures allows us to set the driving pressures and PEEP more properly and safely. We can differentiate the respiratory mechanics of the lung and the chest wall separately and allows us to determine the amount of energy or power that is used to inflate each (the power exerted on the lung can cause harm, while I don't think the amount of energy to inflate the chest wall can cause harm, though I am not sure about harm to the diaphragm). As I mentioned before, the trans-pulmonary mechanical power might be more meaningful in VILI based on some studies. It helps me separate the components of the compliances,

and I also use it to measure the trans-mural vascular pressure e.g. CVP or PAWP – the pleural pressure.

I acknowledge that inserting, interpreting and troubleshooting those catheters can be time consuming, but our patients deserve we treat them with the best information and technology that we have.

I have those tools built on the ventilators that I like to use compared to the other ventilators that don't and I used them frequently, though admit not on every single patient.

Q6: Thoughts on what mode you use for lung protection, and would you consider the newer modes of ventilation that so called close the loop and automatically adjust to match the changes of the patient's lungs?

Answer: I am not sure that the mode itself is the sole responsible for or against lung protection, but how we clinicians adjust its parameters. In general, I use the pressure-controlled modes versus the volume-controlled ones (less dyssynchronies, more patient freedom, better oxygenation, less pressures, etc.).

I do believe in the newer modes with closed loop ventilation, and I think they are the future of mechanical ventilation though again we are not totally there yet. The ability of the ventilator to monitor the patient many times/second during a single breath, and breath to breath and makes adjustments is beyond any humane capabilities even for the best experienced clinicians. Those modes adjust the tidal volume/flow, RR, Inspiratory time according to the respiratory mechanics and the inspiratory power which are very important, but I also would like to have the PEEP also changed automatically according to the respiratory mechanics. The Intellivent-ASV mode adjust the minute ventilation according to the end tidal carbon dioxide and the PEEP but according to the FiO_2 which I don't really like as I mentioned above.

I use the ASV and AVM modes as they have shown to be more lung protective, require less human input and thus less prone to errors and to disagreements according to clinicians beliefs. Those closed loop modes have been there for a while but as usual we are very slow to adopt them.

Q7: Thoughts on the use of muscle relaxants and permissive hypercapnia as part of your ventilation management for lung protective ventilation

Answer: I do use muscle relaxants occasionally and as briefly as possible but not in every severe ARDS patient. The ICU paradigm changes a lot, we used paralytics very frequently 20-30 years ago, then we shied away from that practice given the benefits of having spontaneous breathing then we are back to paralytics in the severe ARDS. Both paralytics and spontaneous breathing have their own benefits and harms, and both are supported in the literature.

I think the main benefits of muscle relaxants are avoiding patient-ventilator dyssynchronies but now we know much more about those dyssynchronies and know how to modulate most of them so I try to avoid paralytics if I can.

I am all for permissive hypercapnia except in cases of severe Pulmonary hypertension where it can cause more harm worsening the pulmonary artery pressure further leading to right ventricular failure and in brain injury cases too. I try to tolerate higher levels of $PaCO_2$ as long as PH 7.15-7.2 to avoid increasing the pressures, volumes, RR all contributing to VILI. Whether hypercapnia per say is protective or not, I am not so sure we have a good answer.

Q8: Thoughts on proning in your ICU practice

Answer: I love proning and a big fan and believer in it even before the studies showed improved mortality in Mod-Severe ARDS. I was lucky to be trained in my fellowship with our program director believing the same. So we saw firsthand how the prone position can be a simple life saving maneuver. We all know the several mechanisms of how proning can benefit ARDS (reduce lung heterogeneity, reduce V/Q, improved RV function, reduce lung atelectasis by the weight of the heart, abdominal organs, drainage of secretions, etc.). However, despite all the physiologic and mortality benefits, studies show that we remain hesitant to do it even when it shown benefits. Possibly because it is time consuming and the fear of its side effects that really didn't pan to be more than the supine position.

It certainly has been increasingly utilized during the COVID-19 pandemic and hope it continues to be utilized as more clinicians and centers now have experience with it.

I think we should do it early and not wait till we fail to oxygenate and while the lung is recruitable, we have to be patient and not expect the oxygenation and ventilation to improve immediately, also we need to investigate more on who would benefit the best.

Q9: Is ECMO or ECCO2r a solution for many patients with ARDS or are they overused due to the lack of understanding optimal PEEP and lung recruitment?

Answer: I think it is the latter. ECMO is an appealing option but the evidence for it remains unconvincing, the ELSO registry shows the VV ECMO mortality for pulmonary disease about 58% which is much higher than the reported mortality in severe ARDS in general, same situation during the COVID-19 pandemic, the reports are conflicting regarding mortality. They are not readily available in all centers and each center has its own guidelines, along with the risks associated with them makes them less appealing.

The additional problem with ECMO is how do we ventilate the patients on ECMO, some centers use the "Rest the lung" approach so use very low PEEP values that might be harmful as would promote further lung injury. Those strategies need to be investigated further.

I used to work in a tertiary center during the H1N1 influenza pandemic and we got lots of transfers for ECMO considerations and probably less than 5% of those would end up on ECMO, because we would try recruitment maneuvers, APRV, HFOV, Proning, inhaled vasodilators, etc. and they would actually improve and be manageable without ECMO.

Now I work in centers that doesn't have ECMO and over the last 10 years, I had less than one hand number of patients that we sought ECMO for.

I never worked with ECCO2r so no personal experience, from what I read is that it hasn't shown to have much benefits but that might change too who knows.

Q10: How do you think we should create more interest on how we should ventilate.

Answer: I believe in Education as the initial and most important step. Changing the culture and get with the new instead of the old classic beliefs. We need more collaboration and set our differences and ego aside and stick with the science.

I also acknowledge that bringing change is a very slow and tedious process.

Unfortunately, most societies, guidelines and hospital protocols are lagging beyond and dictate what clinicians can and can't do and we became robots following tables and diagrams.
Definitely more research data to identify what is helpful and what is harmful, maybe artificial intelligence is the solution? I think so
I am optimistic that our pace to understanding and improvement will continue to pick up eventually.

Thank you