



Bench Study: Performance of three home ventilators

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Mechanical ventilators with noninvasive ventilatory support include new and sophisticated features but may differ in basic performance. Independent bench studies that use specific ventilation scenarios allow for testing and comparison of their operation in conditions that are similar to the clinical setting. The aim of this study was to evaluate the clinical performance of three different home ventilators simulating different pulmonary conditions at different magnitudes of leaks.

Methods

A bench study was completed with the stock models with no modifications of the Astral 150, Breas Vivo 60, and Respironics Trilogy Evo with the single-limb circuit. All were tested in the operating conditions specified by the manufacturer and with the mandatory leak port provided.

Testing was carried out on the ASL500 lung model (software version Sw3.6) with a simulator bypass and leak valve model (SBLVM). Three pulmonary patterns were simulated by a combination of mechanical characteristics of compliance (Csr) and resistance (Raw).

- 1. Obstructive conditions:** Csr = 50 and Raw = 20
- 2. Restrictive conditions:** Csr = 20 and Raw = 5

A breathing rate of 12 breaths per minute (bpm) and inspiratory efforts of -0.5 and -2 cmH₂O were used for the spontaneous ventilation. Leak conditions of 3, 6 and 10 liters per minute (lpm) measured at 10 cmH₂O were used.

The following parameters were set on each of the ventilators tested:

- **Triggering:**
Maximum sensitivity without auto-trigger
- **Case settings:**
Volume control (VCV): Tidal volume (VT) = 500 ml
Pressure support (PSV): Paw = 10 and 20 cmH₂O
- **Ventilatory Respiratory Rate (RR):** 10 bpm
- **Other settings:** default values
- **Standard circuit provided by manufacturer**

After stabilization of the ventilator-lung system, 10 breathing cycles were recorded on the three pulmonary patterns, the two inspiratory efforts and the three ventilatory modes producing 54 different situations. Values captured and compared for each of the ventilators tested included:

- **Tidal volume**
- **Time Delay Trigger (TDT)**
Time from the onset of inspiratory effort (point at which a sudden rise in flow and a drop in Paw is seen) to reach Paw end-expiratory value.
- **Pressure-time Product and 500 msec (PTP500)**
Area under the curve of Paw from the onset of the inspiration to the lower value in Paw. The first 500ms of a cycle. iPTP% is the fraction represented by the actual PTP value out of the ideal area for PTP (100)
- **Asynchrony Index**
Ratio of the rate of the number machine cycles divided by the number of patient cycles per minute, expressed in percentage.



Results

VCV Tidal Volume

Trilogy Evo met the set VT of 500 ml in 15 of 18 conditions. Both the Astral 150 and Vivo 60 were unable to meet the set volume under all of the conditions. Under the three restrictive conditions with low effort, the Astral 150 averaged a VT of only 48.9 ml. The Vivo 60 was not consistent in the conditions in which it did not meet the required tidal volume as seen with a VT of 89.4 ml in the obstructive condition, low effort and high leak and a VT of 75.2 ml in the restrictive condition, low effort and high leak (**Figure 1**).

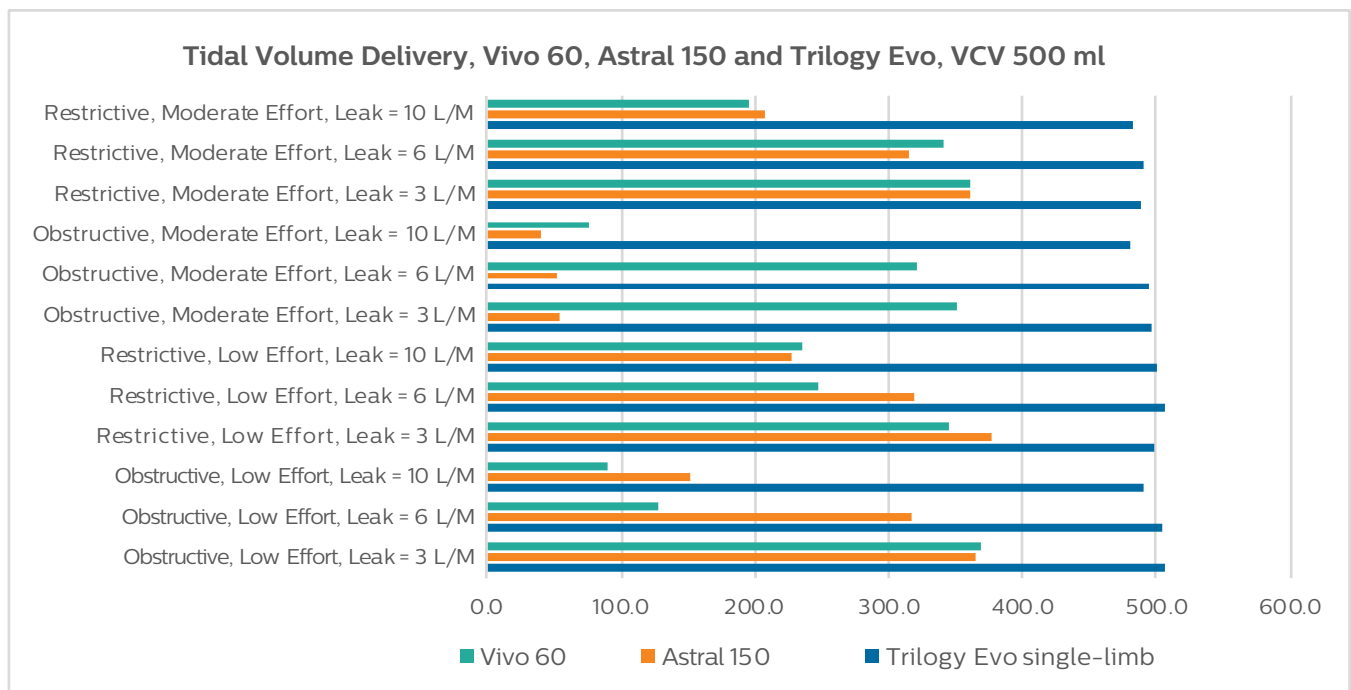


Figure 1: Tidal Volume Delivered in VCV Mode

Pressure support ventilation

In PSV, tidal volumes will be different depending upon the breathing conditions and the mechanical lung condition. In this bench test, both Trilogy Evo and Vivo 60 demonstrated that with a specific condition in both the PSV of 10 and 20 cmH₂O conditions, there were consistent tidal volumes no matter which leak level was set, demonstrating the units compensated for the leaks (**Figures 2 and 3**). The Vivo 60 was unable to deliver as high of a tidal volume compared to Trilogy Evo. The Astral 150 was inconsistent in its delivered volumes across the leak levels in the obstructive conditions with both PSV values.

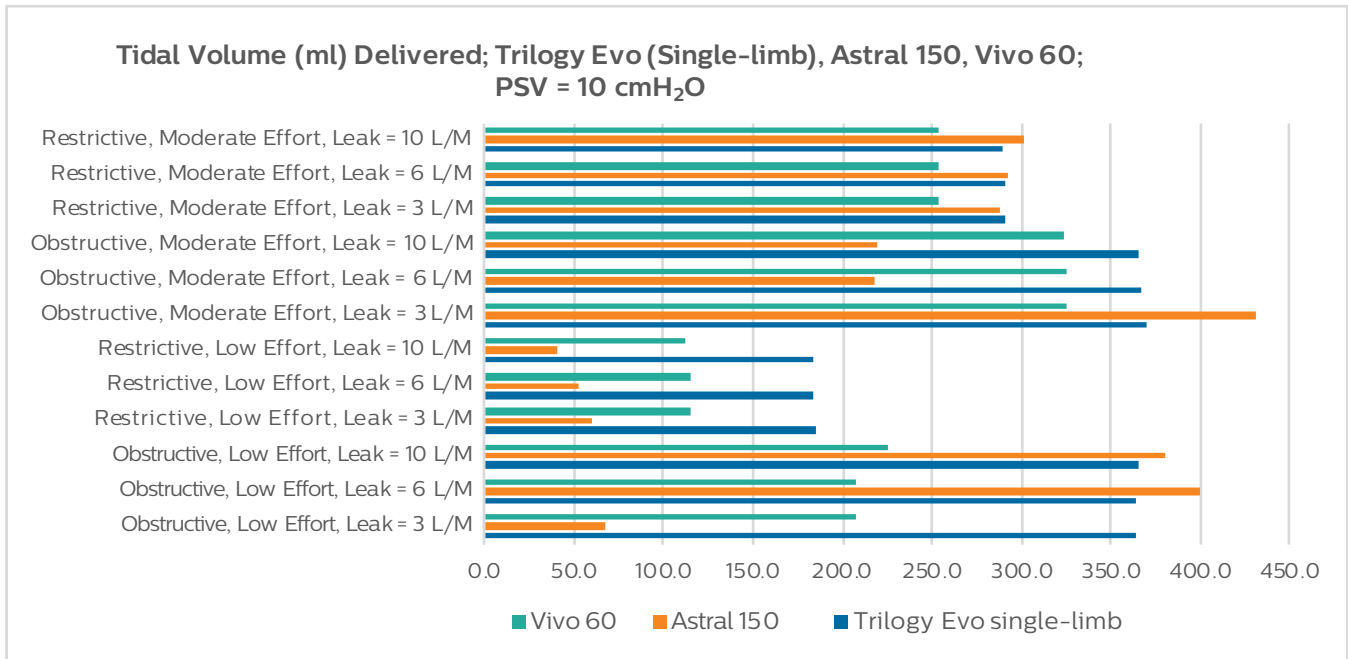


Figure 2: Tidal Volume Delivered, PSV = 10 cmH₂O

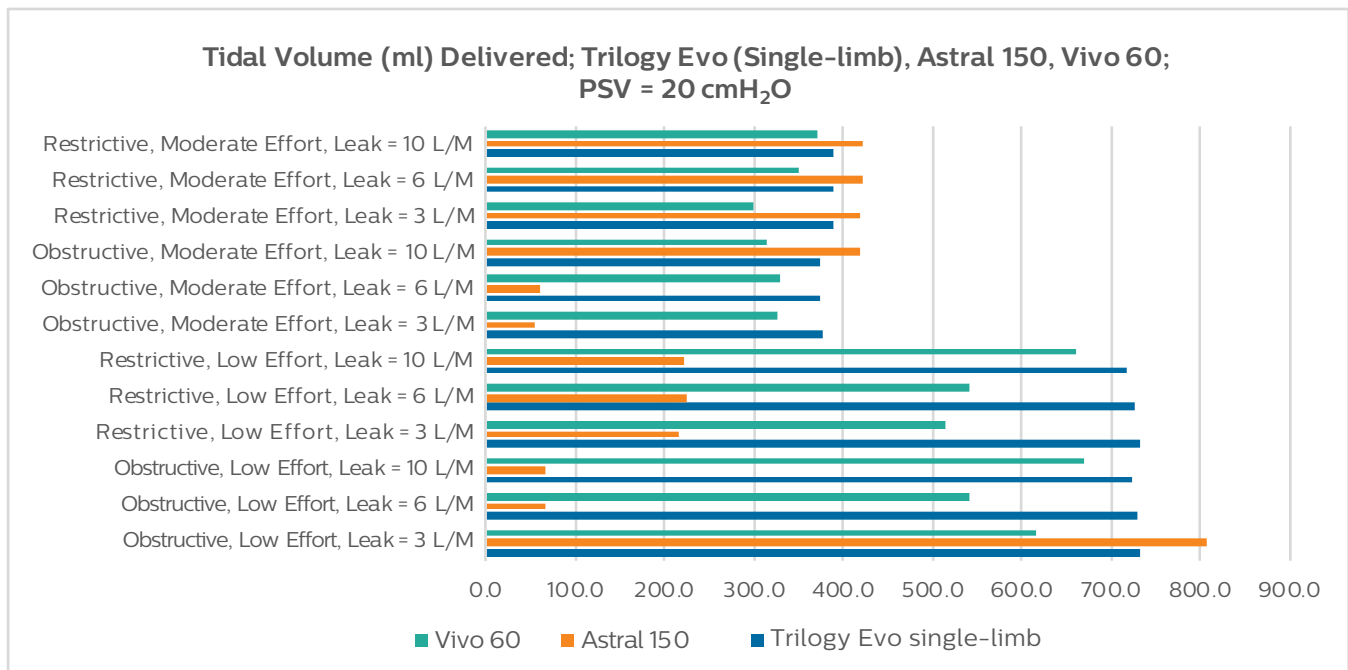


Figure 3: Tidal Volume Delivered, PSV = 20 cmH₂O



Trigger analysis

Trigger delay time (TDT) was tested on all ventilators with a PSV of 10 cmH₂O (**Figure 4**). Some TDT values on the Vivo 60 and Astral 150 were not obtained because of a lack of synchronization. Except in the obstructive conditions with low effort, the most homogeneous values came from Trilogy Evo. The obstructive, low effort condition caused auto-PEEP and produced a TDT double those in the restrictive conditions. In general, Vivo 60 had lower values than the other ventilators, but no trigger could be determined in the obstructive with low effort conditions. Trigger failures in obstructive and prolonged triggers in the restrictive conditions were seen with the Astral 150.

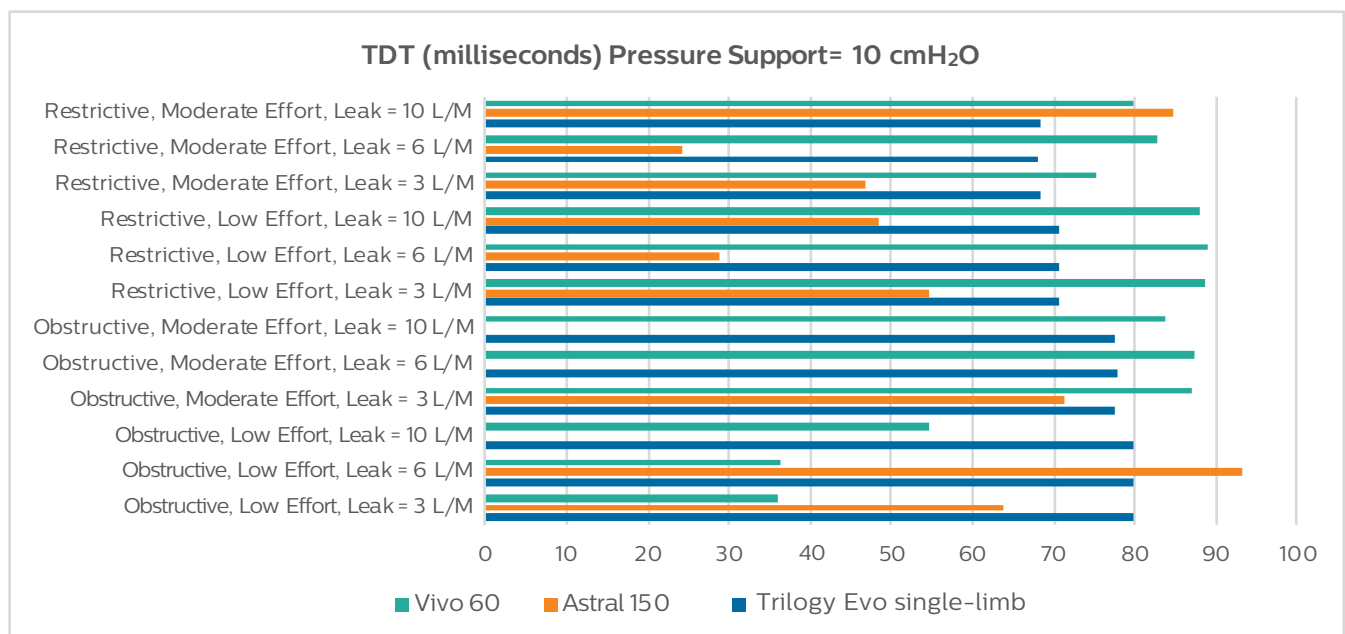


Figure 4: Trigger Delay Time (TDT)

Pressure time product

Results of the %PTP 500 with the Trilogy Evo are the most consistent as compared to the other two ventilators (**Figure 5**). The leaks used did not affect the %PTP, which indicates the ability to compensate for them. As seen with the TDT, the Vivo 60 had PTP values lower than Trilogy Evo but did have conditions in which PTP could not be calculated due to reduced flow. Astral 150 values are higher indicating that a larger effort was needed in order to trigger.

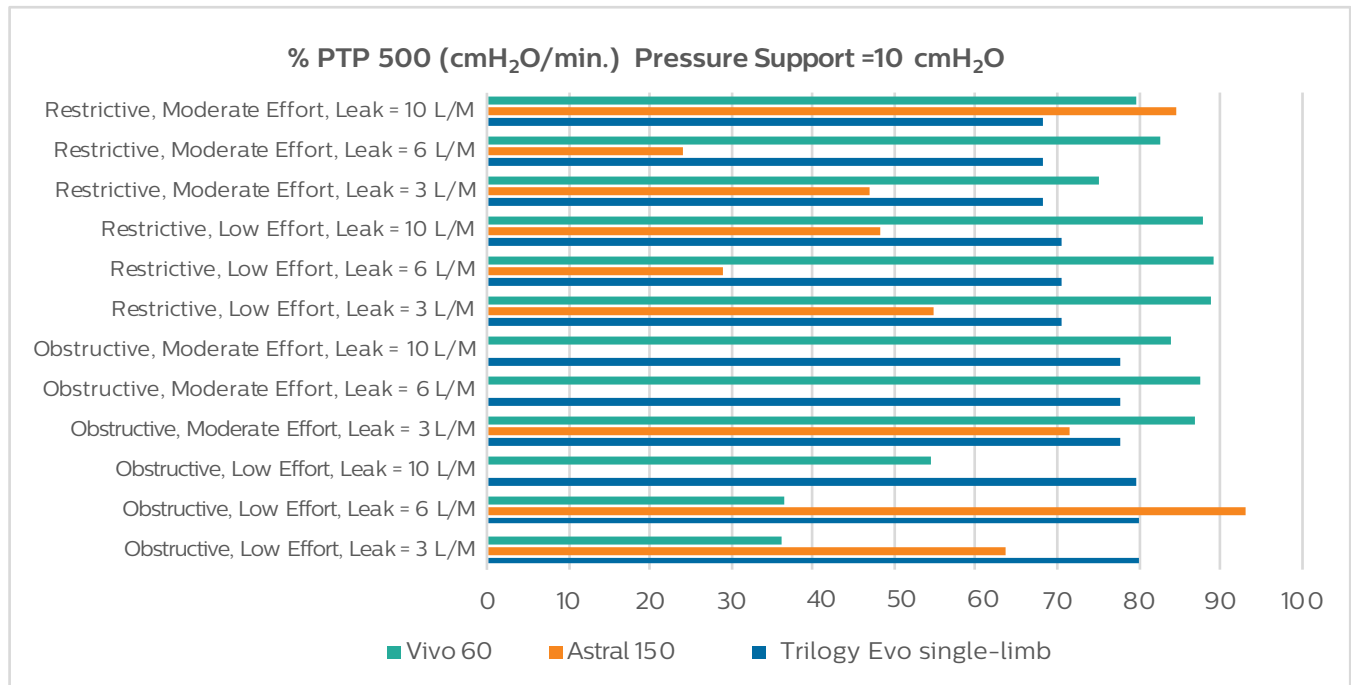


Figure 5: % Pressure Time Product 500

Asynchrony index (AI %)

All ventilators in any of the conditions had very good synchronization (**Figure 6 and 7**). Trilogy Evo synchronized with breathing effort 100% of the time. Astral 150 and Vivo 60 showed lower AI% of between 88 – 94% in some conditions.

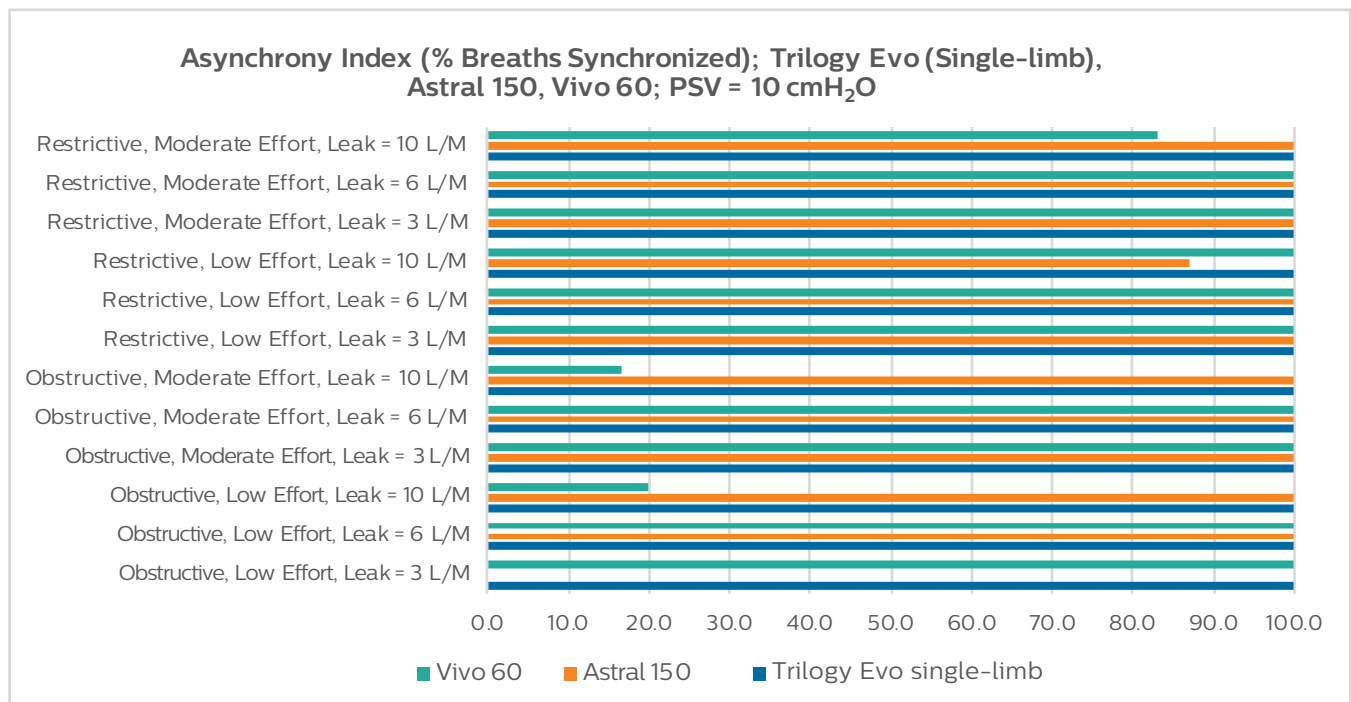


Figure 6: Asynchrony Index (PSV = 10 cmH₂O)

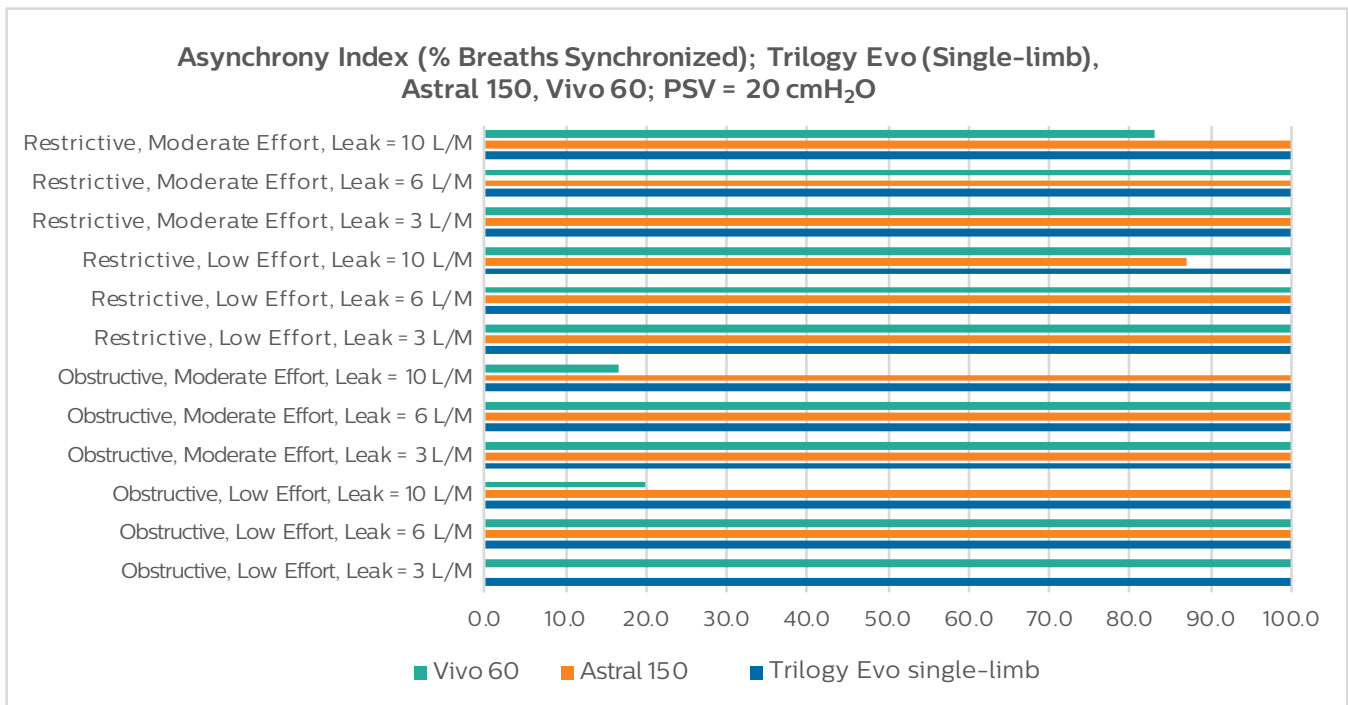


Figure 7: Asynchrony Index (PSV = 20 cmH₂O)

Conclusions:

Major findings of the bench study can be summarized as follows:

- Trilogy Evo was consistently within product specifications for tidal volumes delivery.
- Trilogy Evo and Vivo 60 delivered consistent volumes in the VCV mode with all 3 leak rates demonstrating the ability to compensate for leaks.
- The TDT and PTP% demonstrated that Trilogy Evo has the most consistent triggering ability in the bench mode.
- The asynchrony index in all ventilators was very good in all conditions tested. However, the Astral 150 and the Vivo 60 in PSV 10 and PSV 20 showed an important incidence of auto-triggering and missed triggering (the Vivo 60 only in the obstructive conditions).

