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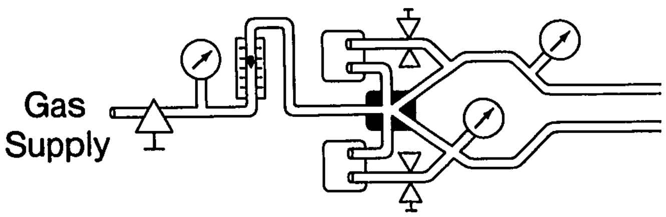
Title: FLUIDIC OSCILLATOR ROLE IN HIGH FREQUENCY VENTILATION

Authors: J.M. Calkins, M.D., S.R. Hameroff, M.D., C.K. Waterson, BSE

Affiliation: Department of Anesthesiology, Arizona Health Sciences Center, Tucson, AZ 85724

Techniques of high frequency ventilation (HFV) have utilized differing modes of gas delivery including positive pressure ventilation (PPV) at rates < 100 min.$^{-1}$ or jet gas streams pulsed by electromechanical (solenoids) or pneumatic/fluidic controllers for higher frequencies (> 100 min.$^{-1}$). This paper describes the use of a versatile, durable, compact, and inexpensive fluidic oscillator system for HFV.

Fluidic Oscillator



The major component of this system (Figure 1) is a bistable fluidic amplifier. With appropriate feedback, this device functions as an oscillator. The supply gas stream flowing through the oscillator tends to preferentially enter one of the exhaust ports and adheres to the wall (Coanda effect). This continues until the pressure in the ipsilateral feedback control port exceeds the pressure in the contralateral control port. This resultant pressure imbalance causes the jet stream to switch to the opposite exhaust. Flow continues in this direction until another control pressure imbalance again switches the stream. Oscillator frequences depend upon supply gas flow and pressure as well as the characteristics of the feedback loops which behave as simple resistance-capacitance (RC) networks.

The two streams which emanate from this oscillator are 180° out of phase. Either stream may be used for patient ventilation. The opposite stream may be vented to the atmosphere, clamped with proper feedback to conserve the quantity of supply gas utilized, or used in concert with the original stream for endobronchial high frequency alternate lung ventilation. Typical operating conditions include power supply pressures and flows ranging from 25 to 40 psi and 15 to 25 l/m. At these values, with adjustment of the variable resistors (needlevalves) and capacitors (bottles), frequencies ranging from 40 to 600 min.$^{-1}$ are easily obtained.

The following cases illustrate clinical application of this system. With appropriate informed consent, this technique was utilized in a high frequency jet ventilation (HFJV) mode for a 1.5 kg neonate with severe bronchopulmonary dysplasia and a 5 kg 3 month infant with severe respiratory failure secondary to coccidiodomycosis.

In each case, a premeasured 14 g catheter was inserted and passed to the outlet of a 4 mm diameter endotracheal tube. The ET tube was connected to a Bourns ventilator circuit with CPAP. Oscillator flows and frequencies were adjusted to obtain desired arterial blood gases (ABG's). In each case, the Bourns ventilator was used simultaneously with the fluidics, but at significantly reduced tidal volumes and rates.

ABG's maintained by the neonate are given in Table I (Case 1). HFJV was introduced and the patient slowly weaned to the fluidic system by gradually reducing ventilator TV and R while simultaneously increasing oscillator flows and frequency from 150 to 430 min.$^{-1}$.

TABLE I - ABG's

					ABG	
HFJV freq$_1$ min^{-1}	Bourns rate$_1$ min^{-1}	TV ml	CPAP CmH$_2$O	F$_I$O$_2$	PO$_2$±SEM torr	PCO$_2$±SEM torr
CASE 1						
-	80	28	3	1.0	42.7±2.2	86.5±4.5
164	30	12	4	0.7	59.8±3.5	73.5±3.5
430	-	-	-	0.6	59.5±6.3	62.1±3.7
CASE 2						
-	80	75	6	1.0	42.0±2.5	39.7±2.7
225	5	65	6	1.0	66.0±3.5	49.0±6.2
100	5	65	6	1.0	94.3±9.7	47.1±4.9

The improvement in the first child's PO$_2$ between the separate Bourns system and both the combination Bourns/Fluidic and fluidic system is significant ($p < 0.01$ and $p < 0.05$ respectively) despite the F$_I$O$_2$ reduction from 1.0 to 0.6. Significant changes between the Bourns and fluidic systems ($p < 0.01$) were also obtained for PCO$_2$. Throughout the procedure (~6 weeks), the neonate breathed spontaneously. Serial chest x-rays suggested resolution of emphysematous blebs and interstitial air. Chest tube air leaks present with Bourn's breaths were not evident with HFJV. Chest tubes were eventually removed.

ABG's maintained by the 3 month infant are given in Table I (Case 2). After implementation of HFJV, significant improvement of PO$_2$ ($p < 0.05$) was obtained with the combination system. The change in PCO$_2$ was not significant. Unfortunately, each baby eventually succumbed to his underlying disease process. HFJV provided improved supportive care for these patients.

A simple fluidic system can operate clinically in a number of ventilation modes. The advantages of utilizing these systems for HFV include compactness, versatility, simplicity, and reliability. By inserting a catheter through an endotracheal tube wall, HFJV can be used in concert with a CPAP-ventilator circuit with either spontaneous or controlled respirations.