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Vacuum Settings and Fluid Flow Rates in Oocyte Aspiration Needle Sets

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Preamble:

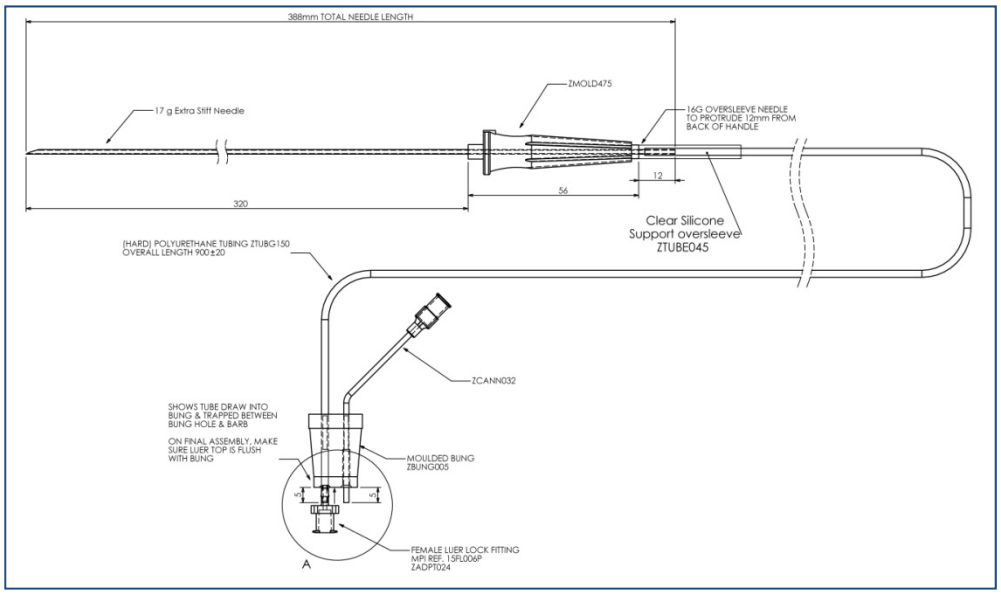
With the increasing use of smaller gauge needles to minimise operative trauma and the introduction of longer tubing sets to aid equipment management in the OR; many users are finding that harvesting flow rates can be adversely affected resulting in increased aspiration times. The logical solution of increasing the applied vacuum causes concern for the safety of the harvested oocytes. This report provides the theoretical background to the problem and confirms the solution. An Excel spreadsheet is also available with this paper so that readers may experiment with various vacuum combinations and to see the effects obtained.

Vacuum Source:

The Rocket® Craft Pump (Craft 1984) and derivatives have been in reliable service for over 20 years and it is the most commonly found vacuum source in IVF clinics around the world. The pump will deliver a 'low' vacuum of between 0-200mmHg and a 'high' vacuum of up to 440mmHg. Suction or vacuum in this experimental model is more accurately described as a *pressure gradient.* Gauges have a 'green' zone up to 100mmHg, later versions to be introduced in 2009 have been amended to 200mmHg.

The Needle and Tube Set:

Illustrated is a typical single lumen needle complete with tube set. The soft silicone bung is inserted into a 'Falcon' style tube and the vacuum source attached to the angled cannula.



When activated, the pump evacuates the reservoir (typically a glass bottle water trap) and creates a pressure gradient such that follicular fluid is drawn down the needle and tubing set into the Falcon tube where it is captured.

The distal end of the needle is the higher and the Falcon tube the lower point of the pressure gradient which dictates the direct of fluid flow.

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Flow Rates:

The flow rate of any fluid through a tube is governed by the following equation (Kaye & Laby. 1995) where:

$$v = \frac{\pi \rho r^4}{8(Pa.s)l}$$

$$\text{Velocity} = \frac{\pi \text{ x pressure x radius}^4}{8 \text{ x viscosity x length}}$$

The variables in our aspiration needle model are:

1. Internal diameter of the needle/2 (*radius*)
2. Total needle and tube set length (*length*)
3. Vacuum applied, more correctly termed a pressure gradient (*pressure*)
4. Viscosity in this model is assumed to be that of water, although media or follicular fluid may differ slightly, it is ignored in this discussion. (*viscosity*)

It can be determined from the formula that small changes in either the *radius r* which is subject to the 4th power or the *length* of the tube will have a significant effect on the volume flow rate (*velocity v*) for a given *pressure p.*

In an oocyte harvesting set, the primary restriction to flow is the internal diameter of the needle followed by the total length of the tube set.

As the smaller ID needle leads into a larger ID tube, the flow values for each main component have also been calculated separately for more accurate comparison. (Table 1).

In the accompanying spreadsheet, the ID of the needle has been used for the total tube and needle length which is not explicitly accurate is terms of actual flow rates but demonstrates very satisfactorily the changes in flow rate caused by longer and smaller diameter tube sets for a given pressure gradient. The sheet also permits the pressure gradient value to be changed to give an indication of the increase/decrease in flow rate which would result.

Given:

R57602-00-SX – Rocket Single Lumen Needle 17G with 70cm tube set

- Needle length = 388mm
- Needle ID= 1.00mm
- Tube Set ID = 1.32mm (constant in both examples)
- Tube Set Length = 700mm
- Total flow path length = 1088mm

R57602-MX-90 – Rocket Single Lumen 17G with 90cm tube set

- Needle length = 388mm
- Needle ID= 0.9mm
- Tube Set ID = 1.32mm (constant in both examples)
- Tube Set Length = 900mm
- Total flow path length = 1288mm

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Worked Examples:

Needle Type	ID mm	Tube Length mm	-ve pressure mmHg	Flow Rate cm^3s^{-1}
SX (needle only)	1.0	388	100	**1.16**
MX (needle only)	0.9	388	100	**0.76**
MX (needle only)	0.9	388	150	**1.14**
Tube Set (70cm)	1.32	700	100	**1.95**
Tube Set (90cm)	1.32	900	100	**1.52**
Tube Set (90cm)	1.32	900	129	**1.95**

Table 1 shows values used calculate fluid flow rate in a given ID or length of tube for a given pressure gradient. It is clearly demonstrated that the MX needle (0.9mm ID) will require an increased pressure gradient (up to 150mmHg) to produce a similar *flow rate* to the larger bore SX needle with a 1.0mm ID. Similarly an increase in pressure gradient (129 mmHg) is required to overcome the increase in length from 70cm to 90cm in the tubing set.

Flow Rates & Turbulence:

Damage to oocytes in harvesting systems is principally caused by *turbulent flow* which produces eddies and leads to rapid rotation of the oocyte. Turbulent flow can lead to physical shearing stresses on the cumulus sufficient to denude or damage the fragile zona (Reeves et al 1989).

Turbulence is a function of two properties: obstruction and flow rate (*velocity*). It is for this reason that competent manufacturers design needles and tubing sets with as few changes of tubing diameter as possible. Particularly to be avoided are 'luer lock' fittings which create large steps causing significant turbulence at their boundaries with the increased risk of oocyte damage.

In a long or small diameter tubing system, the reduced *flow rate* is a function of the tubing dimensions and the pressure gradient. Therefore, restoring the flow rate to a level normally found in a wider or shorter system (by increasing the pressure gradient) cannot increase the risk to oocytes.

It should be remembered that the 'safe' value of 100mmHg was settled upon at a time when Craft et al were using larger 15G needles (2.3mm ID) and short 40cm tubes sets. Since those times, needle ID's have steadily reduced and tubing set lengths have increased markedly. As a result, an increased pressure gradient is required to restore the fluid flow rate to an acceptable level.

One theoretical, but often quoted, concern is increased hydrostatic pressure variations causing cellular damage. However, as (intracellular) fluid is a non compressible medium, as is the surrounding follicular fluid, the cellular volume remains unchanged regardless of the pressure gradient.

References:

Craft I, (1984) 'Clinical Methodology' British Journal of Hospital Medicine 90-10216

Kaye and Laby. (1995) 'Tables of Physical Constants'. 16th Edition. National Physical Laboratory. UK

Reeves G, Scott R T, et al (1989) Journal of Assisted Reproduction and Genetics Volume 6, Number 6 / December, 1989