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Aquaflo pump *vs* FMS 4 pump for shoulder arthroscopic surgery

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A prospective controlled trial was carried out to compare two different fluid delivery systems used for shoulder arthroscopy. One an advanced pump system that controls both pressure and flow of fluid delivered, the other an air-driven diaphragm pump that only controls fluid pressure. Blood loss, presence of bleeding vessels and visual clarity were parameters used to assess the pump systems. There was no difference between the pumps in straightforward shoulder procedures. However, complicated and prolonged procedures benefited from the use of the advanced pump system.

Irrigation pump systems are used to improve visibility in shoulder arthroscopic surgery. Sophisticated pumps can adjust rapidly to fluid requirements. The Fluid Management System (FMS 4) pump manufactured by Orthoconcept combines inflow and outflow in a single compact unit and has a lavage facility controlled by a foot switch. However, these pumps are expensive and infrequent use may also not help to cover costs in a small hospital.

A disposable pump system to perform arthroscopy has recently become available in the United Kingdom. It is called 'Aquaflo' pump and is described as a total displacement pump that makes use of a special diaphragm. This diaphragm separates compressed air and the irrigation fluid. The diaphragm vibrates to the flow of air. A reduction valve controls the pressure of the air. The maximum pressure delivered is equivalent to 14 feet of water pressure (6.0 psi—300 mmHg). The frequency of vibration increases according to the pressure delivered. The vibration of the diaphragm transmits pressure into the inflow tube and thereby pumps fluid into the joint.

There were no capital costs involved in the disposable system except for the reduction valve. As we were not sure about the clinical efficiency of this pump compared with the standard arthroscopy pump, we started a trial to answer this question.

Materials and methods

The trial was prospective and carried out at the Royal Berkshire Hospital, Reading. The study aimed to compare clinically the use of an inflow/outflow pressure and flow-regulated pump (FMS 4—Fluid Management System pump) with an inflow pressure-regulated pump (Aquaflo). The study was limited to arthroscopic subacromial decompressions in the shoulder.

Twenty patients who underwent shoulder arthroscopy proceeding to arthroscopic subacromial decompressions were included in the study. Patients who were on medication (other than ordinary analgesics and anti-inflammatories) and patients who had any systemic diseases like diabetes mellitus, liver failure, bleeding disorders, were excluded from the study. This was to

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exclude any extraneous factors liable to affect the total blood loss. The 20 patients were assigned randomly to different groups by means of opening a sealed envelope kept in the operating theatre and were divided into two groups of ten.

Group 1 (F=FMS 4) was the control group and patients in this group had an arthroscopic subacromial decompression performed with the aid of the FMS 4 pump. The inflation pressure of the pump was maintained constantly at 50 mmHg.

Group 2 (A=Aquaflo) was the test group and the patients in this group had an arthroscopic subacromial decompression performed with the aid of the Aquaflo pump. We maintained the inflation pressure at 150 mmHg, which delivers an intra-articular pressure of 50 mmHg.

All the shoulder arthroscopies were performed in a standard manner *(1)*. Patients were positioned on their side with the affected shoulder uppermost. Skin traction of 4.5 kg was attached to the ipsilateral forearm of the patient. All procedures were performed by one of two surgeons (SAC or JB). A posterior portal for the arthroscope and a lateral portal for the shaver were used.

We compared the efficiency of the pumps by assessing three variables. One variable was objective and the other two were subjective. The objective variable was to compare the amount of blood lost in each procedure. The irrigation fluid bags of saline were weighed pre- and postoperatively. The difference between the pre- and postoperative weight of the saline bag was directly converted as the volume of the fluid used for the particular procedure. The product of this volume and the cell count of the effluent gave us a count of the total red cells lost in each patient. We ignored the actual volume change contributed by the presence of blood in the effluent. This was because the volume of blood was negligible in comparison to the volume of effluent. The effluent from the arthroscope though bloodstained was too dilute for direct haematocrit detection. It was also too heavily bloodstained for an ordinary dipstick test. We thus performed a cell count using a Bayer H*2 cell counter. The Bayer H*2 normally dilutes the sample to a ratio of 1:625. This would have rendered some of the less bloodstained samples uncountable. We performed a manual dilution of 1:9 with saline on all the samples. An initial sedimentation period of 15 min was allowed to remove pieces of tissue that would have otherwise blocked the cell counting equipment. This procedure was consistent and reproducible.

The two subjective variables were the opinions of the surgeon regarding 'the presence of bleeding vessels' and the 'visual clarity'. The presence of bleeding vessels was documented as 'None', 'Few' or 'Many'. The 'visual clarity' was recorded as 'Good', 'Average' or 'Poor'.

The number of 'red blood cells lost' during each

Table I. Details the patients

ID	*Age*	*Sex*	*Procedure*	*FMS/Aquaflo*	*Surgeon*	*Time for op*	*Fluid used*	*RBC in 1 ml×10⁹*	*Total RBC×10⁹*	*Presence of bleeding vessels*	*Visual clarity*
1	54	F	ASD	A	B	15	2245	3.22	7229	None	Good
2	42	F	ASD	F	C	14	3200	20.27	64864	Many	Poor
3	43	F	ASD	A	C	25	2300	18.28	42044	Few	Good
4	57	M	ASD	F	C	20	2000	6.91	13820	None	Average
5	31	F	ASD	A	C	20	2500	27.18	67950	Few	Good
6	59	F	ASD	F	B	28	3665	32.16	117866	Few	Average
7	63	F	ASD	F	C	15	2500	6.00	15000	Many	Poor
8	47	F	ASD	A	C	20	2450	37.30	91385	Many	Average
9	50	M	ASD	A	C	20	1700	32.10	54570	Few	Good
10	46	F	ASD	F	B	18	2025	7.37	14924	Few	Average
11	79	M	ASD	A	C	15	2700	2.00	5400	Few	Good
12	65	M	ASD	A	B	22	3600	2.92	10512	Many	Poor
13	56	M	ASD	A	C	15	2100	42.70	89670	Many	Poor
14	75	M	ASD	A	B	20	2900	9.83	28507	Few	Average
15	61	M	ASD	F	C	20	3100	16.43	50933	Few	Average
16	53	F	ASD	A	C	20	3700	8.14	30118	None	Good
17	30	M	ASD	F	C	20	2700	5.07	13689	Many	Average
18	54	M	ASD	F	C	15	2100	7.83	16443	Many	Poor
19	64	F	ASD	F	C	15	2400	11.06	26544	None	Good
20	60	M	ASD	F	B	25	4220	9.52	40174	Few	Average

F=(FMS pump) Group 1—the Control group
A=(Aquaflo pump) Group 2—the test group

Table II. Student's *t* test on total red blood cells lost

Criteria	*Group*	*Mean*	*SD*	*t stat*	*df*	*Statistical difference*
RBC	'1' or 'F'	37425.80	33503.13	0.361	18	None
	'2' or 'A'	42738.49	32318.88			

Group '1' (Patients who had arthroscopy with the FMS 4 pump)
Group '2' (Patients who had arthroscopy with the Aquaflo pump)

procedure was analysed statistically by the independent *t* test.

'The presence of bleeding vessels' and 'the visual clarity' were analysed separately by the χ^2 test.

Results and analysis

The ages of the 20 patients ranged from 30 to 75 years; the median was 54.45 years. There were 10 males and 10 females. The two groups were comparable for age and sex. The details of all the patients with the results are given in Table I. There were no postoperative complications in any of the patients.

Assessment of the 'Red Blood Cells lost' (Table II), 'the presence of bleeding vessels' (Table IIIA) and the 'visual clarity' (Table IIIB) showed no statistically significant difference between the two groups ($P=0.05$).

Discussion

Our objective was to compare a sophisticated and expensive pump (FMS 4) that regulated all the three variables of inflow pressure, the outflow pressure and flow, with a economical pump (Aquaflo) that regulated only the inflow pressure. The results show that for a straightforward procedure like arthroscopic subacromial decompression, there was no difference between these two pump systems. Some previous studies have shown that pumps that control both the pressure and flow were superior to pumps that only controlled pressure. These comparisons have been both in the laboratory *(2)* and in clinical practice *(3)*. However, none of these studies measured blood loss objectively. We believe that blood in the visual field is the single most important factor that impairs visibility. Arthroscopic debris from use of a shaver also impairs visibility. However, this occurs only in arthroscopic surgical procedures and not in diagnostic arthroscopy.

The main drawbacks of our trial are the small numbers and hence the low power of the tests. However, the trial showed clinically significant results.

Even though the pumps were comparable there were differences:

1 The volume of the inflow in the Aquaflo was inadequate even when using two inflow bags. This was more evident when suction was attached to the shaver. The lowest suction deflated the joint and impaired visibility. We applied a partially clamped artery clip on the suction tubing to further decrease the pressure. Unfortunately, this increased tissue extravasation and swelling.
2 Pressure was the only variable that could be adjusted in an Aquaflo. On the contrary, both the pressure and the volume of flow could be adjusted in the FMS 4 pump.
3 Separate suction was necessary while using Aquaflo pumps and manual adjustments had to made to the suction during the procedure. This disturbed the smooth progress of the procedure. However, the FMS 4 pump had suction coupled with the inflow. This automatically controlled the inflow according to the suction.
4 In the Aquaflo pump, the inlet tubes leading from the normal saline bags to the shoulder had to be completely free of any air bubbles. The presence of air bubbles in the tubing interfered with the procedure and decreased the pressure of the fluid delivered to the joint.
5 The vibration of the diaphragm in the Aquaflo pump sometimes created vibration/flickering of the image on the television.
6 The company literature for the Aquaflo pump states that the "pump automatically stops if outflow was occluded". This did not happen in the clinical setting, where a joint cavity exists between the inflow and outflow. Any occlusion beyond the joint only increased the extravasation from the joint. The pump stopped only if the inflow tube was occluded before its entry into the joint.

Table IIIA. χ^2 test on 'presence of bleeding vessels'

Group	*None*	*Few*	*Many*
'1' or 'F'	2	4	4
'2' or 'A'	2	5	3

$\chi^2=0.881$ with two degrees of freedom (statistical significance—None)

Table IIIB. χ^2 test on 'visual clarity'

Group	*Good*	*Average*	*Poor*
'1' or 'F'	1	6	3
'2' or 'A'	6	2	2

$\chi^2=0.056$ with two degrees of freedom (statistical significance—None)

7 In addition to the above shortcomings, the definite advantage of the FMS 4 pump was the lavage system. The lavage quickly cleared the arthroscopic field when clouded by a storm of shaver debris.

In our opinion, the Aquaflo pump is not a system that would replace advanced pump systems, but is adequate for straightforward arthroscopic shoulder surgery. It is an inflow diaphragm pump and constant attention must be paid to balance the outflow to maintain distension of the joint. The real advantage is that it is a cheaper and a practical alternative to automatic pumps for straightforward procedures.

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