Review Articles

MEDICAL EQUIPMENT FOR MULTIPLACE HYPERBARIC CHAMBERS
Part III: Infusion pumps and syringes

Jacek Kot
National Centre for Hyperbaric Medicine, Institute of Maritime and Tropical Medicine, Gdynia, Medical University of Gdansk, Poland

Kot J: Medical equipment for multiplace hyperbaric chambers. Part III: Infusion pums and syringes. Europ J Underwater Hyperbaric Med 2006, 7(2): 29-31. All medical devices introduced into the hyperbaric chamber should be of an appropriate design and fit for use in the hyperbaric environment and they should be certified by the manufacturer for hyperbaric conditions. However, until now only several medical devices are CE marked for usage in hyperbaric chambers. Therefore users often need to perform themselves checking of the medical equipment needed for continuation of intensive care during hyperbaric treatment. To make this task easier, this paper presents review of reports of usage of medical devices under increased pressure. Part 1 concerned devices for monitoring and cardiac support. Part 2 described mechanical ventilators and Part 3 devotes to infusion pumps and syringes.

Hyperbaric Oxygen Therapy, Medical Equipment, CE Marking

INTRODUCTION

The review concerning monitoring devices and cardiac support was presented in the Part 1 of this paper (1). Part 2 of this paper reviewed the mechanical ventilators (2). Part 3 presentes a review of infusion pumps and electric syringes.

INFUSION PUMPS AND SYRINGES

The cheapest method of fluid delivery in multiplace chamber is using a free fall system. The only pitfall is to regulate the volume of gas compartments in fluid bottle and in a drip chamber of the fluid line during the HBO session according to changing pressure. Using flexible PVC pre-packed solutions allows avoiding of the hazards of too fast fluid application, blood draw-back into the line and introducing gas into the blood vessel which are hazards of gas bubble entrapped in the rigid bottles being exposed to changing pressure. Nevertheless due to changes of gas volume in the drip chamber the user must constantly adjust the fluid flow. Therefore this method cannot be used for administration of fluids and drugs which need to be administered at the constant rate. Some electrical syringes and infusion pumps are needed inside hyperbaric chamber to accurate titrated delivery of drugs as a part of intensive care, usually for inotropic agents and sedatives.

As all medical devices being introduced into the hyperbaric chamber, infusion and syringe pumps need to be carefully checked for additional hazards created by their usage in hyperbaric conditions. The important point in the pre-compression checking is validation of performance under increased pressure (3), because there are several reports of significant reduction in infused volume during the HBO session for different models (4, 5, 6, 7).

Knowledge of type of the infusion system and its construction helps to predict its behaviour under hyperbaric conditions. Syringe pumps are delivering the fluid be a mechanical pushing of the piston syringe. Therefore – theoretically – one can assume that pressure should not influence the performance of such system. However, there are some reports of reduction of fluid delivery rate during changes of pressure (4, 7). In cases where there is a reduction in infused volume during the compression phase followed by an increased infused volume after decompression, a non-equilibrated gas space in the system should be suspected, space between the sealing rings of the rubber cap of the syringe plunger being one possibility (4). If there is a reduction of the infused volumes in all phases of the HBO session other explanations are needed (4). One is “backlash” which is due to delayed engagement of the drive system. The other is “breakfree” force required to overcome the resistive forces of the syringe. Both reasons are not related directly with the changes of pressure, but are responsible for inaccuracy in flow control even at normobaric conditions.

Infusion pumps can deliver the fluid using different mechanisms. If the infusions pump is a vacuum-type device (eg. Coopdeq, Osaka, Japan), in which there are two chambers divided by a partition and a vacuum is produced in one chamber when the other one is filled with fluid, the influence of changing pressure on vacuum chamber is so large, that they are unsuitable for hyperbaric environment (8). Also all peristaltic pumps controlled by a drip chamber are presumed to be unsuitable for use inside the hyperbaric chamber, because during compression the drip chamber fills with fluid and the device stops working. This was confirmed for several different models (5). Other mechanisms (spring or balloon-type) can be generally used in the hyperbaric conditions (8), however their performance can be significantly influenced by the hyperbaric conditions and therefore they must be checked before usage for critically ill patients.

Up to now only one syringe pump is CE marked for usage in hyperbaric environment. It is Pilot HYPERBARIC (Fresenius Vial S.A.). This pump allows administering fluids from the syringes of volumes 20, 50 or 60 ml with a

preset rate in a range of 0.1 to 400 ml/hour with a possibility to program a bolus. The pump has a 6 V battery to be located outside the hyperbaric chamber ensuring 7 hours of autonomy at 5 ml/h flow. It has been tested at 7 ATA.

Some other models – even if not CE marked for hyperbaric conditions - have been already tested in hyperbaric environment. The list of electrical syringes and infusion pumps which have been tested under hyperbaric conditions either with positive or negative results is presented in the Table 1.

Table 1. Electrical syringes and infusion pumps used in multiplace hyperbaric chambers

Electrical syringe / infusion pump	Testing conditions and comments	Remarks	References
Atom 235 (Atom Medical Corporation, Tokyo, Japan)	Tested to 2.8 ATA. It is a syringe pump. Average reduction in infused volume during the compression phase was 7% of the pre-compression value.	OK	4
Ballon Infuser (Baxter, USA)	Tested to 2 ATA. It is a balloon-type infuser. The effect of increased pressure was minimal.	OK	8
Baxter Colleague CX (Baxter International Inc., USA)	Tested to 6 ATA. It is a volumetric pump. The volume error was within the limit of 10%.	OK	9
Baxter PCA Infusor (Baxter Healthcare Corporation, Deerfield, IL, USA)	Tested to 2.3 ATA. It is a patient-controlled analgesia infusor. There was increased flow by up to 10% at increased pressure.	OK	10
CADD-PCA 5200 PXC (Pharmacia Deltec Inc., St Paul, MN, USA)	Tested to 1.9 ATA. At 2 ATA it stops functioning. It is a PCA pump. In this case it was used for epidural analgesia.	UNSUITABLE	11, 12
Coopdeq (Osaka, Japan)	Tested to 2 ATA. It is vacuum-type infuser. Pump output was approx. doubled at 2 ATA.	UNSUITABLE	8
DPS (Becton-Dickinson & Company, Franklin Lakes, NJ, USA)	Tested to 2 ATA. The pump stopped between 2 and 2.1 ATA.	UNSUITABLE	12, 13
Easy-pump MZ-257 (Lemi-Op Ltd., Bnei-Brak, Izrael)	Tested to 6 ATA. It is a peristaltic infusion pump controlled by a drip chamber. It failed to function completely beyond a chamber pressure of 1.4 ATA.	UNSUITABLE	5
Graseby 3100 (SIMS Graseby, Watford, UK)	Tested to 1.6, 2.5 and 6 ATA. It is a syringe pump. It did not respond to any of the control button under pressure of 2.5 ATA.	UNSUITABLE	5, 6
Imed 965 (Alaris Medical Systems, San Diego, CA, USA)	Tested to 6 ATA. It is a volumetric infusion pump. For the most part a deviation was within 10% (20-40% at the low infusion rates during compression).	OK	5, 6
IMED Gemini PC-1 (ALARIS Medical Systems, Inc., USA)	It is a volumetric pump.	OK	15
IMED Gemini PC-2TX (ALARIS Medical Systems, Inc., USA)	Tested to 6 ATA. It is a volumetric pump. The greatest variation in the output was 21%.	OK	15
Imed series (Life Care, Abbot)	It is a volumetric pump.	OK	16
Infusion Dynamics Power Infuser (Infusion Dynamics, Inc., USA)	It is a volumetric pump.	OK	17
Infutec 520 (Infutec Medical Systems 2000 Ltd., Lod, Israel)	Tested to 6 ATA. It is a volumetric infusion pump. For the most part a deviation was within 10%.	OK	5
IVAC 770 (IVAC Corp., CA, USA)	It is a volumetric pump.	OK	16
IVAC Alaris Medsystem III (ALARIS Medical Systems, Inc., USA)	Tested to 6 ATA. It is a volumetric pump. The greatest variation in the output was 17%.	OK	14, 15
IVAC P300 (Ivac Medical Systems, Basingstoke, UK)	Tested to 2.5 ATA. Released flows were equal at different pressures.	OK	12, 13
MiniMed 506	Tested to 2.4 ATA and also to altitude of 10,000 feet. It is an insulin pump. Functional without modification.	OK	17
MTP military (Medical Technology Products, Inc., USA)	It is a volumetric pump.	OK	14
Rateminder III (Criticon)	It is a volumetric pump.	OK	16
SE 200 (Vial Medical, France)	It is a syringe pump.	OK	16
SE 400B (Vial Medical, France)	It is a syringe pump.	OK	16
TE-171 (Terumo Inst., Tokyo, Japan)	Tested to 2 ATA. It is peristaltic type pump. A deviation was ±3.6%.	OK	18
TE-311 (Terumo, Leuven, Belgium)	Tested to 2.8 ATA. It is a syringe pump. The change in delivery rate was 0.5%.	OK	19
TE-312 (Terumo, Leuven, Belgium)	Tested to 2.8 ATA. It is a syringe pump. The change in delivery rate was 0.5%.	OK	19
Terumo STC-3121 (Terumo Inst., Tokyo, Japan)	Tested to 2 ATA. It is a syringe pump. The discrepancies from the set rate were from -4% to +3%.	OK	20
Terumotec (Terumo Inst., Tokyo, Japan)	Tested to 2 ATA. It is a spring-type infuser. The effect of increased pressure was minimal.	OK	8
Top (Top Inst., Tokyo, Japan)	Tested to 2.5 ATA. It is a syringe pump. The output of the syringe was reduced by 10% during the compression.	OK	7

CONCLUSIONS

Regardless of the model of electric syringe or infusion pump used, the user should be aware of the hazard related to the use of such devices to minimize the risk of critical incidents for seriously ill patients receiving hyperbaric treatment. This is of most importance for inotrope–dependent patients. Such patients need accurate continuous haemodynamic monitoring and a preparedness to rapidly titrate inotropes to physiologic endpoints (4).

REFERENCES

1. Kot J. Medical hyperbaric equipment for multiplace chamber. Part 1: Devices for monitoring devices and cardiac support. Europ J Underwater Hyperbaric Med 2005; 6(4): 115-120.
2. Kot J. Medical hyperbaric equipment for multiplace chamber. Part 2: Ventilators. Europ J Underwater Hyperbaric Med 2006; 7(1): 9-12.
3. Swaby K, Swaby G, Fife C, Smith L. Testing considerations for fluid infusion systems used in the hyperbaric environment. Undersea Hyperbar Med 2003; 30(3): 262.
4. Story DA, Houston JJ, Millar IL. Performance of the Atom 235 syringe infusion pump under hyperbaric conditions. Anaesth Intensive Care. 1998 Apr; 26(2): 193-195.
5. Lavon H, Shupak A, Tal D, Ziser A, Abramovich A, Yanir Y, Shoshani O, Gil A, Leiba R, Nachum Z. Performance of infusion pumps during hyperbaric conditions. Anesthesiology. 2002 Apr; 96(4): 849-854.
6. Shupak A, Lavon H, Ziser A, Abramovich A. Performance of infusion pumps under hyperbaric conditions. UHM 1999; 26(suppl): 69-70.
7. Dohgomori H, Arikawa K, Kanmura Y. Accuracy of infusion pump during hyperbaric oxygen therapy. Undersea Hyperbar Med 2003; 30(3): 216-217.
8. Dohgomori H, Arikawa K, Gushiken T, Kanmura Y. Accuracy of portable infusers under hyperbaric oxygenation conditions. Anaesth Intensive Care. 2002 Feb; 30(1): 25-28.
9. Furnas KR, Davison WJ. Use of Baxter Colleague infusion pumps in a multi-place hyperbaric chamber. Undersea Hyperbar Med 2003; 30(3): 261.
10. Radcliffe JJ, Spencer I. Performance of the Baxter disposable patient-controlled analgesia infusor under hyperbaric conditions. Anaesthesia. 1994 Sep; 49(9): 796-797.
11. Sanchez-Guijo JJ, Benavente MA, Crespo A. Failure of a patient-controlled analgesia pump in a hyperbaric environment. Anesthesiology. 1999 Nov; 91(5): 1540-1542.
12. Levecque JP, Vincenti-Rouquette I, Rousseau JM. Electric pumps and hyperbaric treatment. Anesthesiology. 2000 Aug; 93(2): 586.
13. Vincenti-Rouquette I, Lévecque JP, Schiano P, Rousseau JM, Brinquin L. L' Evaluation du fonctionnement d'un pousse seringue électrique en caisson hyperbare. HIA Val de Grâce, Paris. Ann Fr Anesth Reanim 1999; 18: S158.
14. US NEDU. Hyperbaric-Safe Medical Equipment 2005. http://www.supsalv.org/ nedu/hyperbaric-safe-list.htm.
15. Wreford-Brown CE, Ross D. Assessment of intravenous infusion pumps under hyperbaric pressure in a multiplace chamber. Undersea Hyperbar Med 2003; 30(3): 261.
16. Pelaia P, Rocco M, Di Lauro E, Spadetta G. Safety and HBO Therapy. In Handbook on hyperbaric Medicine. G. Oriani, A. Marroni, F. Wattel (Eds.). Springer-Verlag, Berlin, 1995: 715-736.
17. Fife C, Cetina S. Initial testing of the Mini Med 506 insulin pump in the multiplace hyperbaric/hypobaric chamber. UHM 1997; 24(suppl): 38.
18. Dohgomori H, Arikawa K, Kanmura Y. Accuracy of a peristaltic finger-type infusion pump during hyperbaric oxygen therapy. J Anesth. 2002; 16(4): 294-297.
19. Brauzzi M, Tanasi P. Test of an infusion pump for hyperbaric oxygen therapy. EUBS 2002: 228.
20. Dohgomori H, Arikawa K, Kubo H. The accuracy and reliability of an infusion pump (STC-3121; Terumo Inst., Japan) during hyperbaric oxygenation. Anaesth Intensive Care. 2000 Feb; 28(1): 68-71.

Author's address:
Jacek Kot, M.D., Ph.D.
National Centre for Hyperbaric Medicine
Institute for Maritime and Tropical Medicine Gdynia
Medical University of Gdansk
Powstania Styczniowego 9B
Gdynia 81-519, POLAND
Phone/Fax: +48 58 6222789
E-mail: jkot@amg.gda.pl