Journal of Forensic Radiology and Imaging 5 (2016) 8–14

Contents lists available at ScienceDirect

Journal of Forensic Radiology and Imaging

journal homepage: www.elsevier.com/locate/jofri

Very economical immersion pump feasibility for postmortem CT angiography

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ARTICLE INFO

Article history:
Received 15 September 2015
Received in revised form
30 October 2015
Accepted 17 November 2015
Available online 30 November 2015

Keywords:
Postmortem CT angiography
PMCTA
Low cost
Immersion pump
Virtopsy
Forensic pathology

ABSTRACT

Background: Current postmortem CT angiography (PMCTA) methods lack machines that are low priced and openly accessible. The aim of this technical study was to evaluate the usage of a very economical mobile immersion pump in comparison to a standard roller pump of a heart-lung machine for PMCTA.

Methods: A Barwig Model 0444 immersion pump and a roller pump mounted inside a conventional clinically certified Stöckert Shiley heart-lung machine were used. Contrast agent (water soluble contrast agent dissolved in PEG 200 at 1:20) and PMCTA parameters were same across both methods. Two PMCTA full body scans of a comparable postmortem interval are compared.

Results: Calibrating voltage against flow rate yields a linear relationship for both water and PEG based contrast solution. Imaging yields similar results for both pump methods.

Conclusions: A more widespread and systematic implementation of PMCTA needs the premise of affordable equipment for facilities with tight budgets. Evaluation of an economical pump system is a step into that direction. This study shows that for specific postmortem application, a very low priced immersion pump delivers equal results to a clinically certified costly roller pump.

1. Background

Ten years ago, postmortem computed tomography (PMCT) in forensic medicine gained the addition of postmortem computed tomography angiography (PMCTA), initiated by a ground breaking paper by Jackowski et al. [1].

Postmortem angiography is not obvious due to arrested blood circulation and subsequent postmortem changes. First works on PMCTA focused on contrast agents [1,2] but not so much on the method used for contrast medium circulation.

Since then, postmortem angiography has become increasingly popular both for research and case investigation. Grabherr et al. introduced diesel oil based contrast agent solutions into PMCTA in 2006 [2]. Subsequently, Grabherr co-authored a number of postmortem angiography patents (2009 [3], 2010 [4], 2012 [5] and 2013 [6]). The oil-based contrast agent branded Angiofil® and a dedicated pump termed Virtangio® [7] were then made commercially available through collaborative efforts with Fumedica®, while a working group[1] was spearheaded, employing that particular choice of devices and materials as a de facto-standard also through a series of publications [9–20]. This is an impressive coordinative aspect while one has to acknowledge that academic authors that hold patent applications or commercial licenses are more productive generally [21].

With that, the current leading commercial solution for postmortem angiography has to be regarded to be the Virtangio® machine that is sold in conjunction with the oil-based patented contrast agent Angiofil® [3–6,22]. The Virtangio® machine costs up to around 80 000 CHF, and a single postmortem scan costs an added amount of around 500 CHF (consumables including contrast agent and tubes). Such costs are prohibitively high for many forensic pathologists. The Virtangio® machine offers relatively convenient handling and controls, and at its core, it contains a roller pump.

The choice of a particular pump system is a technical issue and therefore warrants technical considerations. Why PMCTA started out specifically using roller pumps is not clear [1,2,23]. Heart-lung machines [24] contain relatively costly peristaltic or roller pumps [25] also to preserve the integrity of corpuscular blood components [26]. Roller pumps excel in transporting fluids with non-Newtonian characteristics (i.e., non-constant viscosity such as blood, more generally containing emulsions, suspensions, slurries; illustrative examples are ketchup or paint) [27,28]. Postmortem angiography requires homogenous watery or oily solutions to be

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[1] Technical Working Group Postmortem Angiography Methods (TWGPAM): its website lists Lausanne (Switzerland), Hamburg (Germany), Munich (Germany), Toulouse (France), Foggia (Italy), Krakow (Poland), Leicester (Great Britain), Basel (Switzerland) and Leipzig (Germany) (in the order cited [8]).

http://dx.doi.org/10.1016/j.jofri.2015.11.009
2212-4780/

quite simply pumped from a container into the body of a deceased person. More cost-effective and therefore ideal PMCTA pumps may better be inspired by typical oil or water pumps, so we chose a simple centrifugal pump with a small paddle wheel.

Administration of contrast agent solution in PMCTA seems to require a specific flowrate. Ross et al. published a comparison of contrast agents [23], where he described perfusion volumes of about 2000 mL for head, neck, thorax, abdomen and the upper extremities and about 400 mL for the lower extremities; he used a decommissioned pressure controlled heart-lung machine (HL20, Maquet) with a perfusion pressure of around 80 mmHg. Morgan et al. ([29], following [11]) reported an Angiofil® flow rate of 800 mL/Min and a volume of 1200 mL (arterial) and 1800 mL (venous) before adding 500 mL @ 200 mL/min for the “dynamic” phase. Contrast agent solutions such as polyethylene glycol (PEG) substrates exhibit concentration dependent viscosity [30]. Roberts et al. [31] report a flow rate of 10 mL/s (600 mL/min). So from literature, one may assume that approximate flow rates somewhere between 200 mL/min and 800 mL/min should result in acceptable organ perfusion.

Based on the expectation that any centrifugal pump mustering a flow rate of watery or oily fluids as low as 1 L/min would suffice for sufficient vascular filling, we invested into a relatively powerful pump ceiling at a 10 L/min flow rate. As this first feasibility test result exceeded our expectations, this technical note thus describes the first use of this very affordable immersion pump (Fig. 1), effectively achieving immersion pump PMCTA (IP PMCTA, in full nomenclature accordance [32]) that results in data that is equivalent to PMCTA performed with a standard heart-lung-machine (HLM PMCTA) (Figs. 2–4). The aim of this technical study was to evaluate PMCTA using a very economical mobile immersion pump in comparison to a standard roller pump of a heart-lung machine. We show a side by side comparison of first results.

2. Methods

2.1. PMCTA: vascular access, contrast medium, PEG

Water soluble contrast agent and polyethylene glycol (PEG) were used as this has been found to provide a superior quality in postmortem angiographic visualization compared to an oil based approach [23]. Vessels were catheterized at the level of sub-inguinal femoral vessels by an autopsy technician (Cannula PU 14F 100 mm, Sorin Group International SA, Lausanne, Switzerland; 1/4–1/4 straight connector). A water-soluble contrast medium (Optiray 300, Guerbet, Paris, France) was diluted in PEG (PEG 200, Schaerer and Schlaepfer, Rothrist, Switzerland) with a ratio of about 1:20 to achieve a mean density of around 350 Hounsfield units (HU) (calibrated via CT scan of the contrast media mixture) and injected in the arterial vascular system only, using two different pumps: an immersion pump and a heart-lung machine.

2.2. Specification of immersion pump

We used an immersion pump (12–24 V, Model 0444 max. 600 L/h ~10 L/min, 145 g, 30 × 80 mm, 0.9–1.7 A, 40 W, Barwig Wasserversorgung, D-34385 Bad Karlshafen; cost around 16–20 CHF) that we controlled by a variable DC power supply (0–30 V, 0–5 A, power consumption 230 V/AC ± 10% @ 50 Hz, weight 4.95 kg, +5 to +40 °C operating temperature, Basetech BT-305, Basetech, Conrad Electronic SE, D-92240 Hirschau; cost 130 CHF).

The pump is constructed to be safely operated in a submerged position. It is approved for pumping drinking water. Its motor is sealed, it features service free lifetime lubrication also for maintenance free dry runs. Due to the build of the pump, maximal cycle times of 30 min are permissible but for continuous operation in excess of 30 min, voltages not higher than 9 V DC should be applied. Approved operating temperatures are between 0 and 50 °C.

The pump is sold and delivered with an electric cable sealed inside and exiting the pump. The outlet contains a conical

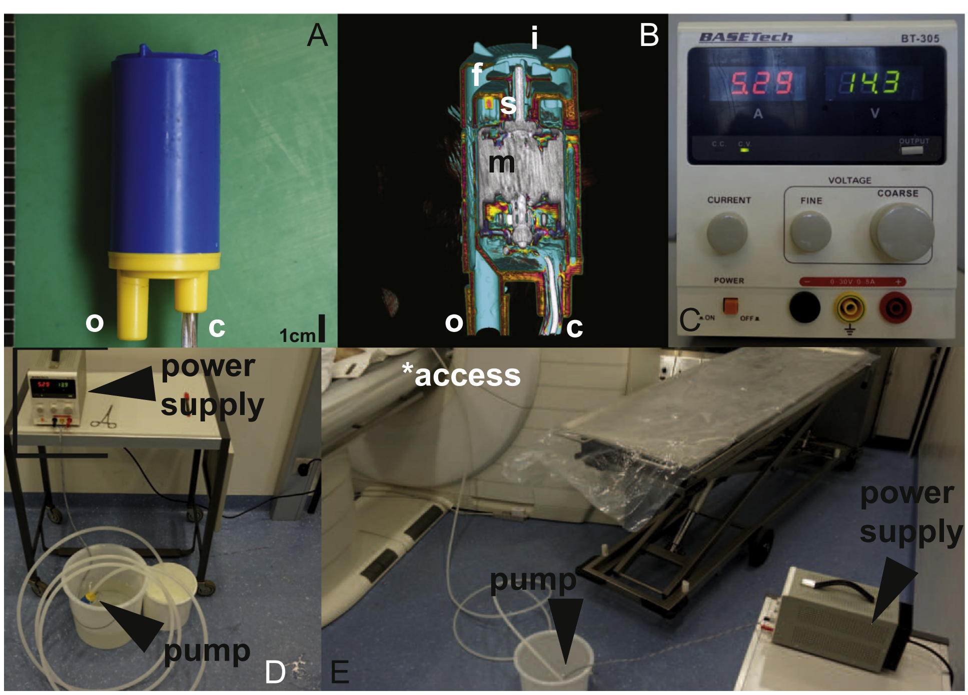

Fig. 1. Immersion pump set up for usage in postmortem CT angiography. The pump (A, B: CT of the pump, view on front facing longitudinal virtual cut surface with inflow (i), outflow and conical tube connector (o), cable (c), motor (m), shaft (s) and paddle wheel (f)) is immersed in the contrast agent solution that we placed into a plastic container (shown in D and E). The pump draws electricity from a voltage controllable power supply (control panel in C; whole device in D, E). Display of the entire setup (E), a PVC tube connects the pump that is immersed inside the contrast agent container to the femoral region (*access) of the deceased positioned on the table of the postmortem CT.