PMMA CAUSES PROLONGED PULMONARY HYPERTENSION DURING VERTEBROPLASTY IN SHEEP

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INTRODUCTION

Poly methyl methacrylate (PMMA) has been widely used in orthopedic procedures for fixation of joint replacements or enhancing the fixation of implants. However, the use of PMMA has been associated with cardiovascular deterioration and even death. More recently, PMMA has also been used for augmenting osteoplastic vertebral bodies which have fractured or are at risk of fracture. This technique is called vertebroplasty (VP). Reported clinical results suggest that VP is a safe and effective technique for providing pain relief 1,2. The reported rate of serious complications is low, but there is the concern that complications are underreported. The main complication is PMMA leakage into adjacent structures 3,4. Transient hypotension 3,4 and fatal Fat Embolism (FE) 5 have also been reported. Recent experimental animal studies showed that the injection of PMMA into vertebral bodies induced FE with transient hypotension as well as baseline changes in mean arterial blood pressure 6-8.

The pathomechanism of cardiovascular deterioration after the injection of PMMA (i.e. FE) remains a highly controversial subject. Substantial research efforts have been put into the investigation of bone mineral cements for replacing PMMA. However, cardiovascular complications may still occur with these materials 9 and the exact role of PMMA in the development of FE remains in the dark.

The aim of the present study was therefore to elucidate the acute effects of injecting PMMA and bone wax into vertebral bodies on the cardiovascular system using an established animal model for VP 6-8.

METHODS

In 8 skeletally mature mixed-bred ewes (2-4 years) 7.0ml PMMA or bone wax were injected unilaterally, into L1 & L2, with 10min in-between injections (approved by local Animal Ethics Committee).

Anesthesia was induced with thiopental and maintained with halothane in a mixture of nitrous oxide and oxygen with positive pressure ventilation.

Arterial, central venous, pulmonary artery and left ventricle pressures were recorded using Statham pressure transducers (P23AC). Heart rate was derived from arterial pulse. Swan-Ganz catheters (CCO 50ºC) to achieve a similar viscosity to the cement. Injection material was filled into 3 ml-syringes with reinforced plungers. As the first augmentation could alter the cardiovascular reaction of the second augmentation, PMMA and wax injections were alternated such that each type was evaluated for first and second injection.

Data were calculated as mean ± SD. Mixed model analysis was used to account for intergroup and intragroup variability. Post hoc analyses were achieved using the paired t-test with the Dunnett’s correction for multiple comparisons. ANOVA and unpaired t-tests were also used for comparisons between the two groups with a significance level of p≤0.05.

RESULTS

There was no significant difference in cardiovascular values before VP (basal) between the two groups. On average, 6.2 ± 0.2ml PMMA or 6.9 ± 0.1ml bone wax were injected, over a period of 30 - 65s.

No difference in the cardiovascular reaction for first and second injection was observed. Augmentation resulted in a two phase response of the cardiovascular system regardless which material was used. First, mean arterial blood pressure (MABP) started to drop ~2s after starting the injection. Secondly, ~11s after starting the injection pulmonary artery pressure (PAP) and central venous pressure (CVP) increased while cardiac output (Q) and left ventricular pressure (LVP) decreased. There was no significant change in heart rate (HR) for both groups. Peak changes for the different parameters were: \( \Delta \text{MABP}_{\text{PMMA}} \) (n=8) -35.8 ± 3.17mmHg; \( \Delta \text{MABP} \) (n=8) -42.0 ± 1.43mmHg; \( \Delta \text{PAP}_{\text{PMMA}} \) (n=6) 18.15 ± 6.61mmHg; \( \Delta \text{PAP} \) (n=6) 20.35 ± 6.29mmHg; \( \Delta \text{CVP}_{\text{PMMA}} \) (n=6) 4.37 ± 0.22mmHg; \( \Delta \text{CVP} \) (n=6) 6.09 ± 1.82mmHg; \( \Delta \text{Q}_{\text{PMMA}} \) (n=8) -2.21 ± 0.01L/min; \( \Delta \text{Q} \) (n=8) -3.88 ± 0.58L/min; \( \Delta \text{LVP}_{\text{PMMA}} \) (n=5) -32.46 ± 2.29mmHg.

In the bone PMMA group, PAP values were still significantly (p<0.05) higher compared to the basal value at 1, 3 and 5min whereas in the wax group PAP had recovered at 3min (Fig. 1). Cardiac output values had recovered at 1min and 3 min for the wax and PMMA group respectively.

DISCUSSION

Augmentation resulted in a two phase response of the cardiovascular system regardless which material was used. Peak responses were similar for both groups; however PAP and Q recovered quicker in the wax group.

The very rapid decrease in arterial blood pressure is likely to be mediated by a reflex inhibition of the heart which has also been suggested by Rudigier and Ritter 9. The peak responses were a result of a reflex vasocstriction of the lung vessels to the embolization of bone marrow particles. Peak responses were therefore mainly associated with the increase in intraosseous pressure during the augmentation causing release of bone marrow contents into the circulation rather than with the cement monomer. The cement monomer however plays a role in the cardiovascular complications during FE. The delayed recovery of PAP and Q in the PMMA group may be due to a vasocostriction effect of the cement monomer on the pulmonary vascular system 10. Alternatively, the presence of cement monomer may increase the concentration of coagulation factors in the circulation.

Differences between clinical VP and the used animal model pertain to the limitations of this study and have been discussed previously 6. This study elucidated for the first time the exact role of the cement monomer in the acute cardiovascular changes during FE. Potentially serious cardiovascular complications may occur during VP regardless of the augmentation material used. Alternative materials may be advantageous for VP as well as arthroplasty due to the shorter recovery time. We recommend continuous invasive monitoring of cardiovascular parameters during VP.

REFERENCES