Temperature Elevation after Vertebroplasty with Polymethyl-Methacrylate in the Goat Spine
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Introduction: Vertebroplasty for the treatment of osteoporotic fractures is gaining in popularity due to the immediate and long-lasting relief of pain, the relative simplicity of the procedure and the low complication rate. A substantial part of the complications is probably related to two properties of the cement: firstly, the viscosity of the cement influences the risk of extracorporeal cement leakage and its potentially harmful sequelae. Secondly, the polymerization of methyl-methacrylate can cause a temperature elevation high enough to lead to tissue necrosis. In the present study, the thermal effects of vertebroplasty with PMMA cement are quantified in an animal model to provide data concerning the risks of tissue-damage.

Materials and Methods: After approval from the local institutional review board, four Dutch milk-goats (± 3 years old) were obtained for vertebroplasty of L3, L4 and L5. After access to the pedicles a drill and increasing diameter mills were used to create a cavity in the vertebral body. Before cement injection thermocouple probes were placed at the intravertebral bone-cement interface (1), the epidural space right above the cavity (2) and in the center of the cranial disc space (3). The correct position of the probes was verified with fluoroscopy (fig 1A). The systemic body temperature was measured by an intranasal probe. Twenty grams of Simplex P® cement was prepared for injection. The cement was injected through the right pedicle until clean cement flowed out the left pedicle. All excess cement was manually removed. Five minutes after the start of cement mixing the temperature of the three probes was recorded at regular intervals (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 120, 150, 180, 210, 240, 300 and 360 seconds). Upon completion of the experiment, the animal was killed with barbiturates and the lumbar spine was removed and frozen (-20º C). After sawing mid-sagittally and macroscopical inspection, the cement in the vertebral bodies was removed and the cavities were determined (fig 1B). Subsequent reaming of all the cancellous bone out of the vertebral body enabled us to measure the total intracorporal volume. The cavity volume divided by the intracorporal volume yielded the filling-percentage. The Wilcoxon Signed Ranks Test, in which p = 0.05 denoted significance, was used for statistical analysis of the data.

Results: The surgical preparation took 135 minutes (range 120-150 min.) with a mean bloodloss of 140 ml. The filling of the cavities and subsequent temperature probing of the three levels took approximately another 50 minutes. In one case the tip of a probe moved through a small cortical defect of the vertebral body after cement injection. The results from this location were discarded from the study. The mean systemic body temperature was 36.8º C. (range 35.5-38.2º C.) at the time of cement injection. At t=0, the mean temperatures of the bone-cement interface, epidural space and disc space were 36.1, 35.8 and 36.2º C. respectively. The mean peak temperature at the interface was 44.6º C. (range 38.7-58.7º C.). In the epidural space, the mean maximum temperature was 37.0º C. (range 35.3-38.5º C.) and in the center of the disc space a mean temperature maximum of 37.5º C. was reached (range 35.5-40.3º C.). In all three locations the difference between the temperature measured at t=0 and the peak temperature was significant (p<0.005). In nine vertebral bodies, the maximum temperature measured at the bone-cement interface exceeded 40º C. (mean peak 45.8º C.), which lasted for an average of 124 seconds (range 50-350 sec.). In one case, the temperature in the disc exceeded 40º C and this lasted for 30 seconds. In the other eleven discal and twelve epidural locations the temperature was always below 40º C. Macroscopical inspection of the split spines did not reveal any extracorporeal leakage of the cement. The mean volume of the cavities measured 0.8 ml. (range 0.6-1.1 ml.). Since the average intracorporal volume measured 3.6 ml., the resultant mean filling percentage was 22% (range 18-26%). In nine vertebral bodies of three goats the shortest distance from the probes to the cement was measured, and in one goat the values could not be obtained. In these vertebral bodies the distance from cement to the epidural probe ranged from 1.9 to 5.8 mm. (mean 4.6 mm.) while in the disc space the distance to the cement ranged from 3.2 to 6.3 mm. (mean 4.4 mm.).

Discussion: In a recent study, pertaining human histology after vertebroplasty with PMMA cement, Togawa et al. noted some foci of necrotic bone at the bone-cement interface, possibly as a result of thermal damage, from five retrievals.1 In present-day practice, an average of 2-6 ml. cement is recommended for a single vertebral body. This corresponds to a filling-percentage of 8-25%, which is comparable to the percentage calculated from our model (18-26%). The steep increase of the bone-cement temperature curve indicates the vertebral body to be incapable of immediately soaking up all the energy that is generated by the polymerization reaction. However, the temperature/time graph (fig 2) representing the mean temperature for each time interval, demonstrated the efficacy of the goat spine to disperse thermal energy even if this was present for a prolonged period of time. Our results can be related to the in vitro findings by Deramond et al., who measured temperatures in human cadaveric vertebrae after injection of 10 ml. of Simplex P bone cement.2 In their study, the average peak temperature in the center of the cement was higher than what was observed at the bone-cement interface (61.8 versus 44.6º C.). Their mean temperature in the epidural space was 38.5º C, which compares well to our finding of 37.0º C. No comparison could be made with their third probe because a different location was chosen. Taking into account the amount of cement (~10 ml.) that is recommended nowadays and the presence of a possibly protective convection mechanism by the circulation of blood and cerebrospinal fluid, our results as well as their data give reason to speculate that, in clinical vertebroplasty practice, the use of PMMA cement, as long as it remains in the vertebral body, will not cause clinically significant thermal damage. Furthermore, the suggestion that the beneficial effect results from a thermal destruction of nerve-endings in the vertebral body seems less likely in this respect.

Figure 2: Graph demonstrating the mean temperature for each interval.

Figure 1A: AP fluoroscopic image showing the position of the probes. Figure 1B: Photograph of the split spine demonstrating the probe position and cement in situ.

Reference:

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