Introduction: Cancer patients often suffer from painful fractures when the presence of metastatic tumour diminishes the mechanical integrity of the bone. While in the past stabilization was often done after fracture, there has been a shift to aggressively treat patients with prophylactic fixation. Intramedullary nailing is an effective method for prophylactic stabilization of the femur, however this technique has been shown to result in the development of high pressures in the intramedullary canal leading to the potential of fat and tumour embolization. Studies have shown that intramedullary pressurization levels over 200mmHg predict the formation of fully configured emboli, and that a level of 25mmHg can be used as a safe conservative baseline below this level snow-flurry (small amount of bone marrow) is not seen on transoesophageal echocardiograms). Studies have shown that venting of the canal reduces pressures recorded in both preparation and nailing of intact femurs but not always to acceptable levels for avoidance of embolization. As well, many studies only look at peak pressure values, while duration of elevated pressures has also been shown to be an important factor in predicting embolization. A model is needed to determine the ability of venting alone to reduce pressurization during prophylactic fixation of metastatically involved femurs, and to identify the movement of the tumour tissue during intramedullary nailing. Therefore, the scope of this study addresses two questions: Does the addition of vents, both distally and proximally result in sufficiently lowered pressures in prophylactically nailing femurs with proximal lytic lesions? And, what is the effect of the reaming and nailing on the displacement of the tumour tissue within the femur?

Methods: Six pairs of fresh frozen human cadaveric femurs (mean age 81.7 ± 10.7 years) were used. All the specimens were x-rayed to eliminate any gross pathology and to select the appropriate intramedullary nail size (Zimmer MDN Femoral Nail, Warsaw, IN). Once defrosted, the femurs were examined for cracks or scoring. Femurs with a significant amount of scoring were used as the vented specimen, otherwise one femur from each pair was randomly selected for venting. Each matching femur was nailed unvented.

To simulate a lytic metastatic proximal lesion, a bone core was removed from the anterior side of the proximal femur, opposite the lesser trochanter. Breast tissue was used to simulate metastatic tumour, and was inserted in to the cored area. The simulated tissue was dyed green to monitor its displacement in the canal. An endcap of cortical and trabecular bone was reattached with bone cement to seal the tumour within the femur.

Two external pressure transducers (GP-50, Intertechnology, Toronto, Canada) were used to measure pressures at the proximal and distal ends, and connected to the intramedullary canal via plastic hollow tubing (diameter of 4.5mm). The distal pressure sensor was located in the medial supracondylar region at the level of the metaphyseal flare. The proximal pressure sensor was inserted posteriorly within the simulated tumour. Two 4.5mm diameter stents were inserted on the lateral side in each of the vented specimens, located at the same level as the pressure transducers in the proximal and distal positions. The placement of the stent and pressure tubes were verified using a fluoroscope to make sure their location would not interfere with reaming or nailing.

Pressure generated in each surgical step, including insertion of vents, repeated reaming, and nailing was recorded. Statistical analysis was done using a repeated measures ANOVA design and linear regression (SPSS/PC). A qualitative assessment of tumour displacement was observed through the movement of the dyed tissue.

Results: Effect of Venting on Maximum Pressure: Venting significantly reduced the maximum pressures generated during intramedullary nailing in both distal and proximal locations (p<0.05) (Figure 1). Venting in the distal end reduced the mean maximum pressures by 54% (range 18-90%). Venting in the proximal end reduced the mean maximum pressures by 57% (range 19-90%). Distally, in both the vented and non-vented specimens, the mean maximum pressure was greater than 200 mmHg. In every specimen pressures rose above 25 mmHg (Table 1).

Effect of Venting on Time Interval of Elevated Pressure: Venting had a significant effect (p<0.05) on decreasing the length of total time above both 200mmHg and 25mmHg for distal pressures (Table 1). The data showed a trend towards decreasing the interval of total time spent above 25mmHg in the proximal pressure.

<table>
<thead>
<tr>
<th>Location</th>
<th>Vented</th>
<th>Non-vented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal</td>
<td>205.1±132.3</td>
<td>542.6±186.3</td>
</tr>
<tr>
<td>Proximal</td>
<td>45.6±21.8</td>
<td>106.0±36</td>
</tr>
</tbody>
</table>

Table 1: Mean maximum pressure and time duration for two thresholds in vented and non-vented specimens.

Discussion: Pressurization of the metastatically involved femur during prophylactic intramedullary nailing is significantly reduced by the use of venting. Venting also resulted in decreased time intervals at elevated pressures. However, venting alone is unable to reduce distal pressures sufficiently to a level below which the development of fully configured emboli does not occur (200 mmHg). Similarly, venting was not shown to be able to reduce proximal maximum pressures within the tumour tissue to levels below the baseline of 25mmHg, creating a potential environment for small amounts of tumour tissue to enter the circulation.

The maximum pressures in this study were all reached within the use of the first two reamers. Previous studies have reported similar findings and comparable maximum intramedullary distal pressures. The proximal pressures reported in this study were on the low end of reported values, likely due to a more proximal positioning of the sensor at the level of the simulated defect. While this allowed the measurement of pressurization within the tumour tissue, the proximal sensor was closer to the entry point of the reamer which may have lessened pressure build up measured proximally.

Tumour displacement is a complication that has not been adequately addressed in intramedullary femoral nailing studies. Throughout the reaming, it was noted that tumour was being displaced distally resulting in spread of the tumour along the canal. This movement of tumour tissue may also have contributed to the high distal pressures measured. Such displacement of tumour tissue may explain the subsequent development of additional lesions along the length of the femur often seen clinically in metastatically involved femurs treated prophylactically with intramedullary nailing. As well, this is a concern as displaced tumour tissue pressurized distally may enter the circulation as emboli and/or potentially increase the spread of metastatic disease.

In summary, we have found that venting alone may be insufficient in preventing complications, with respect to both pressurization and tumour displacement, in the prophylactic nailing of femoral metastases.