## The Cardiopulmonary Effects of Varying Stem Length in Cemented Hip Arthroplasty for Proximal Femoral Metastases

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Surgical interventions for bony metastases to the proximal femur traditionally include endoprosthetic reconstruction, osteosynthesis with a plate-screw construct, and intramedullary nail fracture fixation. In endoprosthetic reconstruction, a cemented long femoral stem is commonly used, as it is believed that a longer stem provides greater protection to the distal femur from future metastases, while also effectively spanning the primary lesion.

It has moreover been hypothesized that the extended length of the prosthesis spreads a larger expanse of cement within the femoral canal, leading to elevated intramedullary pressure and subsequent embolic load. As such, it is linked to increased risk of intraoperative bone cement implantation syndrome (BCIS) characterized by cement-associated: oxygen desaturation, hypotension, embolization, arrhythmias, cardiac arrest, and/or death. Given these concerns, our institution sought to evaluate if the length of the prosthesis itself was a significant variable in contributing to this purported correlation with intraoperative BCIS, hypotension, and oxygen desaturation. METHODS:

A retrospective chart review of patients that underwent cemented hip arthroplasty procedures due to metastatic disease (carcinoma, myeloma, lymphoma) to the proximal femur between October 2018 and May 2024 was conducted.

Intraoperative complications were identified through review of anesthesia and operative reports. Since the exact moments of cementation and implantation were not routinely documented in the anesthesia record, we approximated the timing of these actions to the final third of surgery. Any complication that fell into this interval was considered to be "cement-associated".

Cement-associated hypotension was considered significant if there was a decrease in systolic blood pressure less than 80 mmHg. Cement-associated oxygen desaturation was considered significant if oxygen saturation fell below a threshold of 90%. Systolic blood pressure and oxygen saturation readings were both recorded every three minutes.

To determine hypotension from BCIS, the mean of all the systolic blood pressure readings from the first one and a half hours of surgery were calculated from the anesthesia report. Intraoperative BCIS grading followed Donaldson's proposed severity classifications and were based upon the last third of surgery. Grade 1 BCIS was defined as an oxygen saturation below 94% or a systolic blood pressure drop between 20% - 40% from the calculated average, Grade 2 BCIS was equivalent to an oxygen saturation below 88% or a systolic blood pressure drop of greater than 40% from the calculated average, and Grade 3 BCIS indicated cardiovascular collapse necessitating CPR. RESULTS:

79 patients, including 80 limbs, were found to meet the inclusion criteria for this study. The most common primary bone lesions were found to be lung (n = 20/80, 25%), breast (18/80, 22.5%), and prostate (n = 13/80, 16.3%). The median stem length was 300 mm, ranging from 130 to 350 mm. At the time of data collection, only two patients (2.5%) had distal disease progression of the originally identified lesion, and 47.5% (38/80) of patients had expired (7 lost to follow-up)

There were 9 limbs found to be treated with femoral stems less than or equal to 170 mm (range 130 - 170 mm), 27 between 200 and 250 mm, and 44 between 300 and 350 mm. The instances of Grade 1-3 BCIS, cement-associated hypotension, and cement-associated oxygen desaturation were recorded (Table 1) and compared across stem length groups (Table 2). There was no statistically significant difference in odds ratios for BCIS occurrence, hypotension, or oxygen desaturation between any of the stem length groups.

One patient with known metastatic breast carcinoma to the femur and lung underwent cardiac arrest requiring two bouts of CPR following implantation of a 230 mm stem. Intraoperatively she was noted to have Grade 3 BCIS, cement-associated hypotension and oxygen desaturation. Postoperatively she was found to have a fatty pulmonary embolism and atrial fibrillation with rapid ventricular rate, however had no long-term sequelae. Other post-operative complications included pulmonary embolism (n = 2), deep-vein thrombosis (n = 2), pneumonia (n = 1), atrial fibrillation with rapid ventricular rate (n = 3), hematoma (n =1), and dislocation (n = 3). There were no instances of deep infection or periprosthetic fracture.

## DISCUSSION AND CONCLUSION:

The results of our study suggest that the length of the prosthesis may not be a significant contributing factor in the onset of intraoperative BCIS, hypotension, or oxygen desaturation in cemented hip arthroplasty for patients with metastatic carcinoma, lymphoma or myeloma to the proximal femur. Instead, it may result from the nature of the operation itself, and/or the permeative bone many of these patients possess as a result of underlying disease. This conclusion is supported by the lack of statistically significant differences in odds ratios for these complications across different stem length groups. Additionally, it is substantiated by the trend of higher incidences of BCIS (Grades 1-3) and cement-

associated oxygen desaturation within the ≤170 mm stem group. Despite the lack of correlation we've evidenced between stem length and intraoperative cardiopulmonary complications, we acknowledge the limitations of our study and advocate studies further higher-quality prospective to substantiate our findings. for

	≤ 170 mm		200 – 250 mm		300 – 350 mm	
Intraoperative Complication	Count	Percentage	Count	Percentage	Count	Percentage
BCIS Grade 1	6/9	66.7%	8/27	29.6%	17/44	38.6%
BCIS Grade 2	1/9	11.1%	4/27	14.8%	5/44	11.4%
BCIS Grade 3	0/9	0%	1/27	3.7%	0/44	0%
BCIS +	7/9	77.8%	13/27	48.1%	22/24	50.0%
Cement-associated Hypotension	3/9	33.3%	11/27	40.7%	10/44	22.7%
Cement-associated O2 Desaturation	1/9	11.1%	1/27	3.7%	1/44	2.3%

	Stem Length Comparison	Odds Ratio	P-value
BCIS (Grade 1 – 3) Occurrence	≤ 170 mm vs. 200 – 250mm	3.77	0.245
	≤ 170 mm vs. 300mm	3.50	0.159
	≤ 200 – 250 mm vs. 300 – 350mm	0.93	1.00
Cement-associated hypotension	≤ 170 mm vs. 200 – 250mm	0.72	1.00
	≤ 170 mm vs. 300mm	1.70	0.671
	≤ 200 – 250 mm vs. 300 – 350mm	2.34	0.118
Cement-associated oxygen desaturation	≤ 170 mm vs. 200 – 250mm	3.25	0.443
	≤ 170 mm vs. 300mm	5.38	0.313
	≤ 200 – 250 mm vs. 300 – 350mm	1.65	1.00
	BCIS (Grade 1 – 3) Occurrence Cement-associated hypotension Cement-associated oxygen desaturation	Stem Length Comparison   BCIS (Grade 1 – 3) Occurrence ≤ 170 mm vs. 200 – 250mm   ≤ 200 – 250 mm vs. 300 – 350mm ≤ 200 – 250 mm vs. 300 – 350mm   Cement-associated hypotension ≤ 170 mm vs. 200 – 250mm   Cement-associated oxygen desaturation ≤ 170 mm vs. 300mm   ≤ 200 – 250 mm vs. 300 – 350mm ≤ 170 mm vs. 200 – 250mm	Stem Length Comparison Odds Ratio   BCIS (Grade 1 – 3) Occurrence ≤ 170 mm vs. 200 – 250mm 3.77   ≤ 170 mm vs. 200 – 250mm 3.50 ≤ 200 – 250 mm vs. 300 – 350mm 0.93   Cement-associated hypotension ≤ 170 mm vs. 200 – 250mm 0.72 ≤ 170 mm vs. 200 – 250mm 0.72   Cement-associated hypotension ≤ 170 mm vs. 200 – 250mm 1.70 ≤ 200 – 250 mm vs. 300 – 350mm 2.34   Cement-associated oxygen desaturation ≤ 170 mm vs. 200 – 250mm 3.25 5.38 ≤ 200 – 250 mm vs. 300 – 350mm 1.65

Table 2. Odds ratios and associated p-values, calculated using Fisher's exact test, used to compare intraoperative cardiopulmonary complications among different femoral stem length groups. Significant difference was considered a p-value < 0.05.

Table 1. Count and percentage of intraoperative cardiopulmonary complications seen among patients undergoing cemented hip arthroplasty with variable femoral stem

lengths.