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Trends in survival after surgery for breast cancer metastatic to the brain and spinal column in medicare patients: a population-based analysis

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Abstract

Background—Central nervous system (CNS) metastases are a common occurrence in patients with breast cancer and are identified in up to 30% of patients at autopsy.

Objective—To determine population-based estimates of survival times following surgical intervention for Medicare patients with metastatic breast cancer to the brain and spinal column.

Methods—Female breast cancer patients with metastases to the brain and spinal column and undergoing neurosurgical treatment were identified through the Surveillance, Epidemiology, and End Results (SEER)-Medicare database. Estimates of survival were calculated using Kaplan-Meier estimation and a Cox proportional hazards model.

Results—There were 643 patients who underwent neurosurgical treatment of metastatic disease from 1986–2005. Of these patients, 264 underwent cranial surgery and 379 underwent spinal surgery. There were 40 deaths during the post-operative hospital admission for an inpatient post-operative death rate of 6.2%. Inpatient death has declined by approximately 50% for surgeries performed in the most recent decade; however the 30 day mortality rate of 9.0% has remained constant. The median post-operative survival following cranial surgery was 7.8 months (95% CI 6.2–9.2), 9.4 months (95% CI 6.3–15.7) for laminectomy, and 15.7 months (95% CI 11.9–18.5) for spinal fusion. Survival after spinal fusion has increased by approximately 50% in the recent decade. Patients with increased survival after cranial surgery were younger, had fewer comorbidities, and longer periods from breast cancer diagnosis to surgery. Patients with increased survival after spinal neurosurgery had lower grade lesions and longer time periods from breast cancer diagnosis to surgical treatment.

Conclusion—After surgically treated metastases one-third of cranial patients and one-half of spinal patients are alive at 1 year. The overall post-operative survival has increased over time only for spinal fusion procedures.

Keywords

breast cancer; craniotomy; spinal fusion; laminectomy; post-operative survival

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Introduction

Central nervous system (CNS) metastases are a common occurrence in patients with breast cancer and are identified in up to 30% of patients at autopsy^{1–3}. It has been suggested that the rate of CNS involvement in metastatic breast cancer is increasing although, the mechanism is still under debate and may be due to better control of systemic disease with novel chemotherapies or to improved metastasis detection^{4, 5}. Additionally, biologic factors associated with increased propensity for brain metastasis have been identified such as estrogen receptor negative hormone receptor status and HER2 over-expression^{4, 6–10}.

The neurosurgical treatment of metastatic cancer is an integral component of multi-modality therapy for brain and spinal column metastases. Survival benefit has been demonstrated for the addition of surgical treatment for isolated cranial metastases compared to radiation therapy alone and improved outcomes have also been reported with surgical treatment of spinal column lesions^{11, 12}. Likewise, surgical resection has been suggested to be of benefit in properly selected patients with multiple cranial metastases^{13–15}.

Generally, analyses of post-operative survival have included multiple primary tumor types^{11, 14, 16–18}, although several case series have noted a benefit to neurosurgical treatment specifically for breast cancer patients^{15, 16, 19–21}. A case series of 70 patients with metastatic breast cancer who underwent craniotomy at the Sloan-Kettering Cancer Center demonstrated a median post-operative survival of 14 months²². A recent case series of 87 patients with metastatic breast cancer to the spinal column that underwent surgical treatment documented a median post-operative survival of 21 months²³. Furthermore, in the only large randomized trial of surgical treatment of spinal metastatic disease, patients with breast primary tumors had improved clinical outcomes¹². To date there has not been a large, population-based analysis of outcomes in patients surgically treated for breast cancer metastatic to the central nervous system.

The goal of this analysis was to determine population-based estimates of post-operative survival following the neurosurgical treatment of metastatic breast cancer, including both intracranial and spinal column disease, using data from patients with breast cancer in the Surveillance, Epidemiology, and End Results (SEER)-Medicare linked database²⁴. Population-based survival times associated with surgical treatment in the Medicare population were determined and predictors of survival were analyzed in an effort to provide descriptive summary data to help inform clinicians considering such procedures.

Methods

Patient Identification

Female patients with a primary diagnosis of invasive breast cancer were identified from the linked Surveillance, Epidemiology, and End Results (SEER)-Medicare database. The SEER Program of the National Cancer Institute (NCI) is a population-based registry that contains data covering approximately 10 to 26% of the United States population, depending on the year of the data. Information concerning primary tumor type, patient demographics, initial cancer treatments, and survival are collected in the database²⁵. Through linkage to the Medicare inpatient claims records, information on subsequent hospitalizations and surgical procedures are also obtained²⁶. Female patients aged 65 years and older with breast cancer diagnoses were identified in the Patient Entitlement and Diagnosis Summary Files (PEDSF) covering years 1973–2002, the most recent years available at the time of project application. Linked inpatient claims from 1986–2005 were obtained from the Medicare Provider Analysis and Review (MEDPAR) dataset²⁴. This study was approved by the Partners Human Research Committee.

Age at time of diagnosis of breast cancer, gender, race, and marital status were obtained from the PEDSF data. Due to the small number of minority patients in the dataset, race was coded for the analysis as white and other. Marital status was dichotomized into currently married and other. Other variables regarding the presenting features of the breast cancer were also obtained from the PEDSF file. Estrogen and progesterone receptor status were analyzed as positive, negative, and unknown. Stage of breast cancer at time of the initial diagnosis of breast cancer was dichotomized into stage 4 (metastatic disease) and non-stage 4 cancer. Histologic grade of the tumor was dichotomized into high (poorly differentiated and undifferentiated) and low (well differentiated and moderately differentiated). To minimize the possibility that a metastatic lesion originated in an organ other than the breast and to exclude patients with primary CNS tumors, patients diagnosed with any other primary tumors were excluded from the analysis. Additionally, patients who had a diagnosis given by autopsy report were excluded.

Surgical Treatment of Brain and Spinal Column Metastases

Patients with a primary diagnosis of breast cancer in the SEER database that subsequently developed metastatic disease requiring neurosurgical treatment were identified through the ICD-9-CM diagnosis and procedure codes in the MEDPAR inpatient records. Patients who underwent a neurosurgical procedure and had a diagnosis of metastatic disease to the central nervous system or meninges were identified through the ICD-9-CM diagnosis codes 198.3 and 198.4. The SEER records were used to remove all patients diagnosed with an additional primary cancer either before or after a diagnosis of breast cancer. Given these exclusion criteria, patients with breast cancer and a diagnosis of a neoplasm of unspecified nature of the brain (239.6) or neoplasm of uncertain behavior of the brain, spine, or meninges (237.5, 237.6) were also included in the analysis. Patients with a diagnosis of metastatic disease to bone or vertebral column (198.5) were also eligible for inclusion for spinal surgeries.

Surgical treatments of brain and spinal metastases were then identified using the MEPAR inpatient files. Surgical treatments of metastatic disease were identified by ICD-9-CM procedure codes for patients with the diagnoses listed above for that admission. The following ICD-9-CM surgical codes were included: 01.59 for craniotomy for excision or destruction of lesion of the brain or meninges, 03.09 for laminectomy and decompression, and 81.00–81.08 for spinal fusion. Patients that underwent only diagnostic procedures such as cranial biopsy or spinal biopsy were not included.

Additional clinical and demographic covariates were obtained from the MEDPAR claims data. Source of admission was dichotomized into emergency room admissions and other sources. Medical comorbidity stratification was performed using the Charlson co-morbidity index adapted by Deyo *et al*, for use on ICD-9-CM codes^{27–29}.

Outcomes

The primary outcomes for this study were post-operative mortality including in-hospital and 30 day rates as well as overall post-operative survival time. The date of death was obtained from the Medicare or SEER date of death in the PEDSF dataset. Survival was censored at the latest date at which vital status information was consistently recorded in the PEDSF dataset, August 2006. The initial analysis included descriptive statistics of clinical and demographic information using means, proportions, and standard deviations. Actual mortality rates with N less than 11 were not reportable due to SEER-Medicare patient confidentiality restrictions on reporting results. One, three, and five year estimates of survival were calculated using the Kaplan-Meier estimation and the log cumulative hazard transformation was used to determine 95% pointwise confidence intervals. The effect of clinical and demographic covariates on the timing of the outcome was estimated using a Cox

proportional hazards model. Hazard ratios (HR) were estimated with 95% confidence intervals. Variables found to be significant at $P = 0.10$ in unadjusted analyses were included as candidates in multivariate analyses. The proportional hazards assumption was evaluated for each variable using cumulative score process plots and the Supremum test. Statistical significance was defined as a type 1 error less than 5%. All analyses were two-sided and performed using SAS version 9.2 (SAS Institute, Cary, NC).

Results

From 1986 to 2005, there were 25,278 women with breast cancer in the SEER-Medicare database admitted to a United States hospital with a diagnosis of CNS metastatic disease or CNS neoplasm of uncertain/unspecified nature. Of these patients, 643 (2.5%) underwent neurosurgical treatment; 264 (41%) underwent cranial surgery and 379 (59%) spinal surgery. Of the patients that underwent spinal surgery, 174 (46%) underwent laminectomy without fusion, and 205 (54%) underwent a spinal fusion procedure. Descriptive statistics according to type of surgery are presented in Table 1. The mean age at the time of surgery was 73 years for patients that underwent cranial surgery and 72 years for patients that underwent spinal surgery. Patients that had spinal surgery were, on average, diagnosed with breast cancer at an average age of 65 and patients that had cranial surgery were an average age of 66 at diagnosis. The majority of patients for both types of surgeries were white (90% for cranial procedures and 91% for spinal procedures). The percentage of patients married, the average number of co-morbidities, and the percentage of patients from non-urban areas are also listed in the table. Over half of the patients had moderately or well differentiated tumor histology at diagnosis (62% for cranial surgery patients and 77% for spinal surgery patients) and a minority had stage 4 cancer at diagnosis. Finally, over 50% of the patients did not have data available for the receptor status analysis. Of the patients with data there was a high percentage of tumors negative for estrogen and progesterone receptors in both groups of patients..

Inpatient Death

There were 40 patients that did not survive to discharge from the hospital, for a post-operative inpatient death rate of 6.2%. There was no difference between the overall rates of post-operative inpatient death for cranial compared to spinal surgeries (6.4% cranial vs 6.1% spinal, $P=0.9$). As shown in Table 2, there were significant differences in post-operative inpatient death rates according to decade of surgery ($P=.03$). For surgeries performed in the decade prior to 1996, the inpatient death rate was 8.4%. This decreased to 4.4% for procedures performed in the decade after 1996. The declines in the post-operative inpatient death rates corresponded to a decrease in the post-operative length of stay over time. The mean length of stay for procedures prior to 1996 was 17.7 days (std dev 14.7). This significantly declined to a mean length of stay of 7.2 days (std dev 11.9) for procedures after 1996 ($P<.01$). In order to account for the effect of the decreasing length of stay on post-operative death rates, the 30 day post-operative mortality rates were then examined.

For all neurosurgical procedures, there were 58 patients that died within 30 days of surgery for a 30 day mortality rate of 9.0%. There was no difference between the 30 day mortality rates for cranial or spinal surgery (9.1% cranial, 9.8% spinal, $p=.8$). The trends in 30 day mortality rates per decade are shown in Table 3. The 30 day mortality rate has remained constant following all types of neurosurgical procedures. The 30 day mortality rate was 10.1% for procedures performed in the decade prior to 1996. The 30 day mortality rate for procedures after 1996 was not significantly different (8.1% $P=.4$).

Post-Operative Survival

There was a significant difference in overall post-operative survival for cranial and spinal procedures (log rank test $P<.01$). The median post-operative survival following cranial surgery was 7.8 months (95% CI 6.2–9.2) compared to the median survival after laminectomy of 9.4 months (95% CI 6.3–15.6) and 15.7 months (95% CI 11.9–18.5) after spinal fusion. Observed rates of post-operative survival according to decade and type of surgery are listed in Table 4.

Trends in overall survival according to the decade in which the surgery was performed were determined. The median survival for patients undergoing cranial surgery in the decade prior to 1996 was 7.5 months (95% CI 5.3–10.0). The median survival following cranial surgery in the decade after 1996 was 8.1 months (95% CI 5.8–9.6). The overall survival following cranial surgery did not significantly vary according to decade of surgery (Figure 1a, log rank test $P=1.0$). Likewise, for patients undergoing laminectomy without spinal fusion, there was no difference in overall survival for cases performed after 1996 compared to cases prior to 1996 (Figure 1b, log rank test $P=.8$). However, for spinal fusion, there was a significant increase in overall post-operative survival for cases performed in the decade after 1996 compared to the decade prior to 1996 (Figure 1c, log rank test $P<.01$). For patients undergoing spinal fusion from 1986–1995, the median post-operative survival was 12.4 months (95% CI 8.4–15.7) while the median survival following spinal fusions performed from 1996–2005 increased to 19.6 months (95% CI 12.1–27.1). This represents an increase in the median survival of 7.2 months, or a 58% increase in median post-operative survival.

Predictors of post-operative survival were then determined using univariate and multivariate Cox regression models. Table 5 lists the hazard ratios associated with clinical and histologic variables for cranial and spine procedures by surgical site. For cranial surgery the significant predictors of increased hazards for post-operative death in unadjusted analyses were increasing age at the time of surgery (HR=1.03, 95% CI 1.01–1.05 per year increase in age), increasing Charlson co-morbidity score (HR=1.18, 95% CI 1.10–1.27 per unit increase), the presence of stage 4 disease at the initial diagnosis of breast cancer (HR=1.81 95% CI 1.22–2.69), and short time between diagnosis of breast cancer and surgical treatment (HR=0.96, 95% CI 0.93–0.98 per year increase in time). After multivariate adjustment, decreasing time from diagnosis to metastatic surgery, increasing age at time of surgery, increasing Charlson co-morbidity score, and stage 4 disease at the initial diagnosis of breast cancer remained associated with increased hazards for post-operative death.

The predictors of increased hazards of post-operative death following spinal surgery differed from those following cranial surgery. On univariate analysis, the presence of estrogen or progesterone receptors on tumor histology compared to respective negative receptor status was associated with decreased hazards for post-operative death (HR=0.47, 95% CI 0.28–0.79 for presence of estrogen receptors; HR=0.48, 95% CI 0.32–0.72 for presence of progesterone receptors). After multivariate adjustment, increasing time from the initial diagnosis of breast cancer to neurosurgical treatment was also predictive of decreased hazards for death (adjusted HR=0.97, 95% CI 0.95–0.99, per year increase). Predictors of increased hazards for post-operative death on univariate and multivariate analyses were admission to the hospital through the emergency room (unadjusted HR=1.41, 95% CI 1.10–1.79, adjusted HR=1.53, 95% CI 1.20–1.97) and poorly differentiated or undifferentiated tumor histology compared to well or moderately differentiated histology (unadjusted HR=1.51, 95% CI 1.17–1.95, adjusted HR=1.49, 95% CI 1.19–1.95).

Table 6 presents the 1, 3, and 5 year Kaplan-Meier survival estimates for patients undergoing either cranial or spinal surgery. The results are presented by age categories for cranial surgery as age was a significant predictor of survival only for cranial procedures. As

can be seen from this table, approximately 50% of younger patients undergoing cranial surgery and 50% of all spinal surgery patients survive for at least one year following surgery. Patients over age 70 that undergo cranial surgery have survival rates of 25–30% at one year. Approximately 25% of spinal surgery patients survive for at least three years from time of surgery.

Discussion

This retrospective analysis of trends in post-operative survival after surgical treatment of breast cancer metastatic to the brain and spinal column suggests that a sizeable number of Medicare patients remain alive at one year's time after intervention. Unlike the majority of previous studies that included patients with multiple primary tumor types, our analyses are specific to Medicare patients with breast cancer. Furthermore, other reports generally include patients from a single clinical center, while our analysis incorporates data from a variety of clinical centers and surgeons and thus is more likely representative of the general population of Medicare patients with breast cancer. Although primarily applicable to Caucasian patients by virtue of the available data, our results may be useful for clinical decision making in Medicare patients diagnosed with metastatic breast cancer to the brain or spinal column by providing estimates of survival time after surgical intervention. Given that 10% of women in the United States will be diagnosed with breast cancer and up to 30% of these may have involvement of the brain or spinal column at some point, these data will be useful to a wide number of persons.

There were several notable findings in this analysis. First, the post-operative inpatient death rate has decreased over time. When considering cranial and spinal surgeries together, the inpatient death rate for procedures in the decade prior to 1996 was 8.4%. This decreased to 4.4% for surgeries in the decade after 1996. This finding supports previous work indicating that inpatient mortality rate following craniotomy for metastatic disease has decreased over time.³⁰ On the other hand, the 30 day mortality rate was almost 10% and has remained relatively constant between the two decades. The decline in in-patient mortality coupled with a constant 30 day mortality rate may suggest either a true in-patient mortality rate decrease or a move to discharge the most severely ill patients to an out-patient setting prior to their death. These post-operative death rates are generally higher than those reported from centers specializing in cancer care^{11, 14, 22, 23, 31}. The Sloan-Kettering surgical series of craniotomy for metastatic breast cancer reported a 30 day mortality rate of 5.7% and a rate of 1.3% following craniotomy was reported for lung cancer metastasis^{22, 31}. A single surgeon series of 208 craniotomies for multiple different primary tumors reported also a 1.3% 30 day mortality rate¹⁴. Likewise, for spinal procedures, one inpatient death (1.1%) was reported in the series of 87 patients surgically treated for spinal breast cancer metastases, while a 6% 30 mortality was reported for the surgical group in the randomized clinical trial by Patchell^{11, 23}.

Additionally, the overall post-operative survival times in this study are less than what has been reported in the literature of dedicated breast cancer case series. For patients that underwent cranial surgery, the median post-operative survival was 7.7 months, while patients undergoing spinal laminectomy had a median survival of 9.4 months and patients undergoing spinal fusion had a median survival of 15.7 months. The median survival after craniotomy in the single institution case series from the Sloan-Kettering Cancer Center was 14 months²². A median survival of 21 months after spinal surgery for metastatic breast cancer has been reported in cases series from the M.D Anderson Cancer Center and Johns Hopkins^{21, 23}. There are several potential explanations for these differences. First, the higher death rates in the current report may suggest an overall higher rate of peri-operative mortality and shorter overall post-operative survival time in Medicare patients. Additionally,

our analysis included almost four times as many patients as contained in the prior single institution series. With this larger sample size it is likely that a wider range of patients are included and the results may be more robust. Finally, it is possible that single institution case series may have a selection bias or may actually represent a survival benefit associated with care at a dedicated cancer center. Therefore, this finding may suggest that the peri-operative mortality rates reported in centers specializing in neuro-oncology may not be widely generalizable to the entire population.

This analysis also specifically evaluated changes in overall post-operative survival over time. For cranial surgery, the median post-operative survival for patients that underwent surgery in the decade prior to 1996 was approximately 7 months. This did not significantly change for patients who underwent surgery in the decade following 1996. Survival after spinal surgery, however, did significantly increase over time for patients that underwent spinal fusion. The median survival increased over 50% from approximately 12 months for surgeries in the decade prior to 1996 to almost 20 months for surgeries in the decade after 1996. The overall survival after laminectomy without spinal fusion has not significantly increased over time. There are many possible explanations for this finding including confounding by patient selection; however, the rapid advances in spinal fusion during this time, for example the introduction of intervertebral spinal fusion cages and pedicle screw technology in the mid 1990s, may be related.

Finally, this analysis also identified clinical predictors of post-operative death and generated survival estimates. The predictors were different for cranial and spinal surgeries. It is evident that the predictors of survival after spine surgery are related to the aggressiveness of the breast cancer. The degree of histologic differentiation, the estrogen and progesterone receptor status, and the time from initial diagnosis of breast cancer to spinal surgery were significant predictors. The analysis of receptor status and the effect on survival was limited as over half of the patients had an unknown receptor status. Likewise, admission through the emergency room was predictive of survival only after spinal procedures. The implications of this type of admission are not clear; however it is reasonable to assume this could also be a marker of an aggressive or acute disease process. Patient level information such as age and medical comorbidities were not predictive of survival. Age at the time of surgery, medical comorbidities, and presence of stage 4 cancer at initial diagnosis of breast cancer were predictive of survival after cranial surgery.

Recent interest has focused on the role of age in outcomes after the development of central nervous system metastases. In our analysis, age was a significant predictor for post-operative survival only for cranial surgery. The effect of age on survival after the development of cranial and spinal metastases has been evaluated in multiple reports with conflicting results. In several recent studies of predictive factors for survival after cranial or spinal metastases, age was not a significant predictor^{19, 32, 33}. In an retrospective analysis of 1292 patients with brain metastases from multiple primary tumor types, age greater than 70 was associated with a mild decrease in survival but age 60–69 was not³⁴. In both of the single institution surgical series of craniotomy and spine surgery for metastatic breast cancer, age was not a predictor of survival post-operatively^{22, 23}. A recent secondary analysis of the only randomized trial evaluating surgical treatment compared to radiation therapy of spinal metastases indicated that surgical treatment did not provide superior outcomes in patients older than 65 years of age³⁵.

These results must be interpreted in light of the limitations of a population-level study of post-operative outcomes. First, data on the clinical details of the CNS metastases treated here are not available. Therefore, patients cannot be stratified based on number, size, or surgical complexity of the CNS metastases. The number of cranial metastases has been

shown to be a significant predictor of survival as well as the anatomic segment for spinal metastases^{33, 36}. Additionally, no information regarding additional treatments such as post-operative radiation and chemotherapy can be obtained from the inpatient records. As such, unmeasured confounders may account for differences in reported survival rates. These data do not come from a clinical trial and hence it is likely that patients with better prognosis are more likely to be offered more aggressive surgical procedures such as spinal fusion, resulting in selection bias.

This is the first report to evaluate the trends in survival after neurosurgical treatment of brain and spinal column metastases from breast cancer. Approximately one third and one half of cranial and spinal patients, respectively, are alive at 1 year after surgery. We demonstrate that inpatient death rates following neurosurgical treatment of metastatic disease have decreased in the past decade. The long-term post-operative survival, however, for cranial surgery has remained relatively constant. For spinal surgery, survival after spinal fusion, but not laminectomy alone, has increased in the past decade.

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Figure 1a.

Trends in overall post-operative survival following craniotomy for treatment of metastatic breast cancer. $P=1.0$

Figure 1b.

Trends in overall post-operative survival following laminectomy for treatment of metastatic breast cancer. $P=.8$

Figure 1c.

Trends in overall post-operative survival following spinal fusion for treatment of metastatic breast cancer. $P < .01$

Table 1

Characteristics of patients with breast cancer that underwent surgical treatment of metastatic cancer according to site of surgery.

	Patients undergoing cranial surgery	Patients undergoing spinal surgery
Total number of patients	264	379
Laminectomy (no fusion)	NA	174 (46%)
Fusion procedure	NA	205 (54%)
Age at time of surgery, mean (standard deviation)	73 (5.5) years	72 (5.6)
Age at diagnosis of breast cancer, mean (std dev)	66 (7.5) years	65 (7.7)
Race		
White	238 (90%)	346 (91%)
Other	26 (10%)	33 (9%)
Married	150 (57%)	213 (56%)
Rural or less urban location	21 (8%)	25 (7%)
Mean Charlson Score at surgery (std dev)	6.7 (1.9)	7.1 (1.4)
Elective admission	134 (46%)	156 (54%)
Year of surgery		
1986–1995	107 (40%)	191 (50%)
1996–2005	157 (60%)	188 (50%)
Stage 4 at diagnosis of Cancer	30 (11%)	55 (15%)
Histology		
Poor/undifferentiated	101 (38%)	86 (23%)
Moderately/well differentiated	163 (62%)	293 (77%)
Estrogen Receptor		
Negative	74 (28%)	19 (5%)
Positive	60 (23%)	111 (29%)
Unknown	130 (49%)	249 (66%)
Progesterone Receptor		
Negative	90 (34%)	42 (11%)
Positive	42 (16%)	83 (22%)
Unknown	132 (50%)	255 (67%)

Table 2

Trends in in-hospital death rates following neurosurgical treatment of metastatic breast cancer.

	In-hospital mortality	Surgery prior to 1996	Surgery after 1996	P value
All surgeries	6.2% (40/603)	8.4% (25/273)	4.4% (15/330)	.03
Cranial	6.4% (17/247)	9.4% (10/97)	4.5% (7/150)	.1
Laminectomy (no fusion)	<6% *	<7% *	<3% *	.2
Fusion	8.3% (17/188)	<9% *	<6% *	.3

* Actual value not reportable due to SEER-Medicare patient confidentiality restrictions on reporting results with N<11

Table 3

Trends in 30 day mortality following neurosurgical treatment of metastatic breast cancer.

	30 day mortality	Surgery prior to 1996	Surgery after 1996	<i>P</i> value
All surgeries	9.0% (58/585)	10.1% (30/268)	8.1% (28/317)	.4
Cranial	9.1% (24/240)	11.2% (12/95)	7.6% (12/145)	.3
Laminectomy (no fusion)	9.8% (17/157)	<10% *	<10% *	1.0
Fusion	8.3% (17/188)	<9% *	<8% *	.8

* Actual value not reportable due to SEER-Medicare patient confidentiality restrictions on reporting results with N<11

Table 4

Trends in overall post-operative survival following neurosurgical treatment of metastatic breast cancer.

	Median post-survival, months (95% CI)	Surgery prior to 1996, months (95% CI)	Surgery after 1996, months (95% CI)	<i>P</i> value, log rank test
All surgeries	9.9 (8.5–11.5)	9.7 (7.6–11.8)	10.2 (8.5–12.9)	.1
Cranial	7.8 (6.2–9.2)	7.5 (5.3–10.0)	8.1 (5.8–9.6)	1.0
Laminectomy (no fusion)	9.4 (6.3–15.7)	9.2 (5.9–14.6)	15.1 (4.6–20.1)	.8
Fusion	15.7 (11.9–18.5)	12.4 (8.4–15.7)	19.6 (12.1–27.2)	<.01

Table 5

Predictors of post-operative survival after neurosurgical treatment of metastatic CNS disease

	Cranial Procedures		Spinal Procedures	
	Univariate Hazards Ratio (95%CI)	Multivariate Hazards Ratio (95%CI)	Univariate Hazards Ratio (95%CI)	Multivariate Hazards Ratio (95%CI)
Age at time of surgery (per year increase)	1.03 (1.01–1.05)	1.04 (1.02–1.07)	0.99 (0.98–1.01)	-
Time from diagnosis of breast cancer to surgery (per year)	0.96 (0.93–0.98)	0.97 (0.94–0.99)	0.98 (0.96–1.00)	0.97 (0.95–0.99)
White Race (vs non-white)	0.67 (0.44–1.01)	NS	0.73 (0.50–1.07)	-
Rural location vs non-rural	1.15 (0.72–1.85)	-	1.14 (0.74–1.78)	-
Married (vs non-married)	1.07 (0.83–1.38)	-	0.92 (0.75–1.14)	-
Charlson comorbidity score (per unit increase)	1.18 (1.10–1.27)	1.17 (1.09–1.25)	1.05 (0.97–1.14)	-
Admission to hospital through ER	1.30 (0.97–1.75)	NS	1.41 (1.10–1.79)	1.53 (1.20–1.97)
Poor/Undifferentiated histology vs well/moderately differentiated	0.91 (0.70–1.19)	-	1.51 (1.17–1.95)	1.49 (1.14–1.95)
Positive Estrogen Receptor vs Negative Estrogen Receptor	0.79 (0.55–1.14)	NS	0.47 (0.28–0.79)	NS
Unknown Estrogen Receptor vs Negative Estrogen Receptor	0.72 (0.53–0.98)	NS	0.61 (0.37–1.00)	NS
Positive Progesterone Receptor vs Negative progesterone receptor	0.85 (0.58–1.25)	-	0.48 (0.32–0.72)	0.54 (0.34–0.87)
Unknown Progesterone receptor vs Negative Progesterone receptor	0.77 (0.58–1.03)	-	0.71 (0.50–1.00)	NS
Stage 4 disease at diagnosis of breast cancer	1.81 (1.22–2.69)	1.63 (1.07–2.47)	0.99 (0.73–1.34)	-

Table 6

Peri-operative survival estimates according to type of surgery

Surgery	Cumulative Survival Estimate (95%CI)		
	Year One	Year Three	Year Five
Cranial Surgery: Age 65–69 (n=88)	47.5 (36.8–57.5)	15.5 (8.5–24.4)	6.3 (2.2–13.8)
Cranial Surgery: Age 70–74 (n=97)	29.5 (20.8–38.8)	12.3 (6.5–20.1)	5.6 (2.0–12.3)
Cranial Surgery: Age >75 (n=79)	24.9 (16.00–34.9)	11.6 (5.6–19.9)	3.6 (0.8–1.0)
Spinal Surgery: Laminectomy (All Ages) ^I (n=174)	47.6 (40.0–54.8)	22.7 (16.7–29.3)	9.0 (5.2–14.1)
Spinal Surgery: Fusion (All Ages) ^I (n=205)	57.0 (50.0–63.5)	22.3 (16.7–28.5)	12.2 (7.8–17.7)

^I Age not statistically significant