# Travel Distance to Radiation Therapy and Receipt of Radiotherapy Following Breast-Conserving Surgery

*William F. Athas, Meg Adams-Cameron, William C. Hunt, Andrew Amir-Fazli, Charles R. Key*

Breast-conserving surgery (BCS) followed by radiation therapy is an efficacious alternative treatment to mastectomy for women with early-stage breast cancer *(1,2)*. However, 15%–30% of the women treated with BCS for early-stage disease fail to undergo postoperative breast irradiation, despite the known increased risk of ipsilateral recurrence associated with the omission of radiotherapy *(3–8)*. Older age has been identified as a major determinant of not receiving radiotherapy after BCS *(4,6,7,9)*. Other factors that could account for failure to receive radiation therapy, particularly among younger women, remain to be identified.

Travel distance to a radiation-treatment facility may influence the receipt of postoperative breast irradiation. Radiotherapy that follows BCS typically involves daily treatments (weekends excluded), for a period of 5–6 consecutive weeks. The necessity of long-distance travel may increase the inconvenience or cost of radiotherapy to a point where it simply is not feasible to receive treatment. A study of breast cancer treatment conducted in the mid- to late-1980s in the Seattle–Puget Sound area found that living in a county without a radiation-treatment facility was associated with a 50% lower likelihood of receiving radiotherapy after BCS *(4)*. A similar contemporaneous study in New Mexico *(3)* found no relationship between radiotherapy and travel distance, but the analysis was limited to manual identification of geographic clustering of BCS patients not receiving radiotherapy. In this study, we used a geographic information system (GIS) to measure actual patient travel distances to radiation-treatment facilities to more precisely examine the relationship between travel distance and receipt of radiotherapy after BCS.

For our analysis, all cases of localized breast cancer diagnosed in 1994 and 1995 in female residents of New Mexico were selected from the New Mexico Tumor Registry (NMTR) database. The NMTR, a member of the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program,[1] collects information on all cases of cancer in New Mexico residents by use of the methods previously described *(3,8)*. Native-American women were excluded from the analysis because the NMTR does not record their addresses at diagnosis. Stage of cancer at diagnosis was coded according to the SEER Summary Staging Guide *(10)*, which defines localized cancer as an invasive cancer confined to the organ of origin. For classification of patients by treatment received, we considered all therapy that occurred in the first 4 months of cancer-directed therapy, the standard SEER definition for the first course of therapy. Surgery was classified as either mastectomy or BCS. BCS included lumpectomy or excisional biopsy, quadrantectomy, wedge resection, partial mastectomy, and subcutaneous mastectomy. For the BCS case subjects, we considered that adjuvant radiotherapy was received if the NMTR record documented radiotherapy during the first course of therapy.

The address at diagnosis was obtained for each case subject from the NMTR database and geocoded by use of ArcView 3.0a software (Environmental Systems Research Institute, Redlands, CA). Approximately 70% of the case subjects were geocoded to a unique street address. The remaining 30% of the subjects, most of whom had either post office boxes or rural routes as their addresses, were geocoded to the centroids of their ZIP codes. Twelve radiation-treatment facilities were operational in New Mexico or in nearby areas in 1995. Four facilities were located in Albuquerque, NM; two in Las Cruces, NM; one each in Santa Fe, NM, Roswell, NM, Farmington, NM, and Carlsbad, NM; and one each in El Paso, TX, and Durango, CO. Each treatment facility was geocoded to a unique street address. We assumed that each patient was treated at the nearest facility and used the GIS to calculate the shortest travel distance to it.

A total of 1122 women diagnosed with localized breast cancer were included in the analysis. Of these, 533 (48%) were treated with BCS, and 409 (77%) received radiation therapy following BCS (Table 1). Age was a strong and statistically significant predictor of post-BCS radiotherapy (two-sided *P* for trend <.0001). Among women less than 60 years of age, 83% received follow-up breast irradiation compared with 79% of those aged 60–69 years and 63% of those 70 years and older. After adjusting for the effects of race/ethnicity and travel distance, patients 70 years and older were roughly three times less likely to receive radiotherapy after BCS compared with patients younger than 60 years. Race/ethnicity was not predictive for receipt of radiotherapy following BCS.

After adjustment for age, the likelihood of receiving radiotherapy following BCS decreased significantly with increasing travel distance to the nearest

*Affiliation of authors:* New Mexico Tumor Registry, University of New Mexico Health Sciences Center, Albuquerque.

*Correspondence to:* William F. Athas, Ph.D., New Mexico Tumor Registry, University of New Mexico Health Sciences Center, 2325 Camino de Salud, N.E., Albuquerque, NM 87131 (e-mail: wfathas@nmtr.unm.edu).

*See* "Notes" following "References."

**Table 1.** Effect of age, race/ethnicity, and travel distance to nearest radiation-treatment facility on the likelihood of receiving radiation therapy (RT) following breast-conserving surgery (BCS) for early-stage breast cancer (New Mexico, 1994–1995)

| | No. of case patients | No. who received BCS (%) | No. who received RT following BCS (%) | Odds ratio (95% CI)* | *P* for trend† |
|---|---|---|---|---|---|
| All | 1122 | 533 (48) | 409 (77) | | |
| Age, y | | | | | |
| <50 | 248 | 131 (53) | 107 (82) | 1.00 (referent) | |
| 50–59 | 236 | 141 (60) | 120 (85) | 1.24 (0.64–2.44) | |
| 60–69 | 257 | 112 (44) | 88 (79) | 0.88 (0.45–1.72) | |
| ⩾70 | 381 | 149 (39) | 94 (63) | 0.36 (0.20–0.64) | <.0001 |
| Race/ethnicity | | | | | |
| White, non-Hispanic | 810 | 391 (48) | 295 (75) | 1.00 (referent) | |
| White, Hispanic | 270 | 123 (46) | 97 (79) | 0.84 (0.49–1.43) | |
| Other | 42 | 19 (45) | 17 (89) | 2.01 (0.40–10.2) | |
| Travel distance, miles | | | | | |
| <10.0 | 621 | 298 (48) | 243 (82) | 1.00 (referent) | |
| 10.0–24.9 | 158 | 87 (55) | 75 (86) | 1.22 (0.61–2.45) | |
| 25.0–49.9 | 76 | 40 (53) | 31 (78) | 0.64 (0.28–1.46) | |
| 50.0–74.9 | 79 | 26 (33) | 18 (69) | 0.48 (0.19–1.19) | |
| 75.0–99.9 | 100 | 51 (51) | 29 (57) | 0.26 (0.14–0.50) | |
| ⩾100.0 | 88 | 31 (35) | 13 (42) | 0.13 (0.06–0.30) | <.0001 |

*Odds ratios and 95% confidence intervals (CIs) were adjusted for age, race/ethnicity, and travel distance by use of multiple logistic regression.
†Tests for trend were computed by fitting logistic regression models to continuous values of the variables. All *P* values are two-sided.

radiation-treatment facility (two-sided *P* for trend <.0001). Only 51% of the women living 75 miles or more from the closest facility received follow-up radiotherapy compared with 69% of those living 50–74.9 miles away and 82% of those residing within 50 miles' travel distance. The percentage of women receiving BCS compared with those who received mastectomy did not vary according to travel distance for radiotherapy (data not shown).

To illustrate the travel-distance relationship on a continuous scale, a smoothed plot of the adjusted log-odds and travel distance was produced by use of a generalized additive model (Fig. 1). A square-root transformation of travel distance was used to spread out the data and to provide greater visual clarity for distances less than 20 miles. The likelihood of receiving radiotherapy after BCS increased slightly with travel distance to approximately 10 miles, then declined steadily at greater distances.

Our finding of a significant inverse relationship between travel distance and receipt of radiotherapy following BCS could, in part, reflect an inability to accurately establish administration of radiotherapy for case subjects residing in outlying areas. This seems unlikely, given that NMTR personnel routinely review treatment information at all radiation facilities in the state and nearby out-of-state areas to document therapy as completely as possible. Our substitution of ZIP code centroids for street addresses for those case subjects without a unique address at diagnosis also may have produced a spurious result. Again, this seems unlikely, since travel distances calculated from unique street addresses were strongly correlated (Pearson $r = .97$) with distances calculated

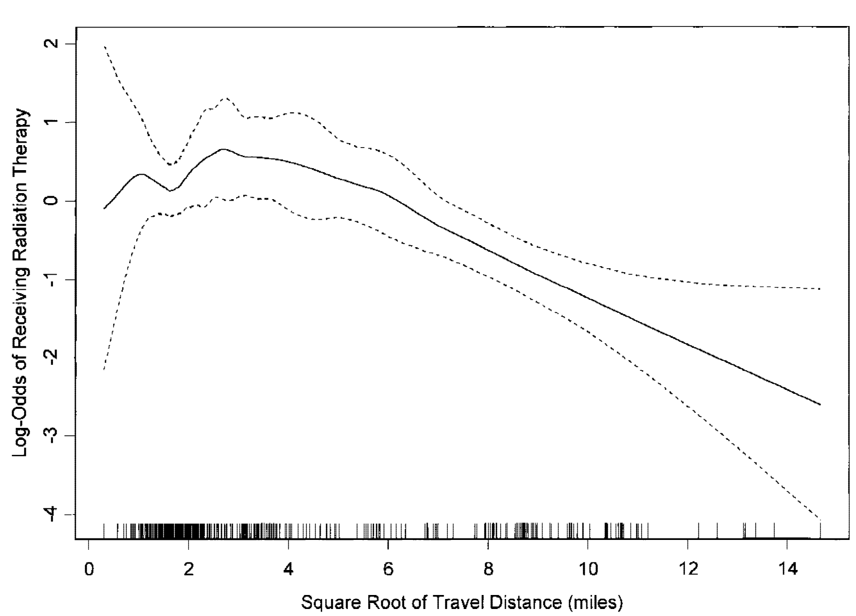


**Fig. 1.** Log-odds of receiving radiation therapy following breast-conserving surgery for early-stage breast cancer is plotted against the square root of travel distance to the nearest radiation-treatment facility. The smooth curve (**solid line**) was produced by use of a generalized additive model *(11)* computed with the "gam" function of S-PLUS *(12)*. The model, a generalization of the usual logistic regression model, allows the effect of travel distance to be incorporated as an arbitrary smooth function. We chose a locally weighted running-line smoother (S-PLUS LOESS) with a span of 0.50. With this LOESS smoother, the fitted value at each observed travel distance is computed from a weighted logistic regression by use of the 50% of the data that are nearest to the target point. The weight given to each data point decreases rapidly with the distance from the target point. The model contained an LOESS term for age and an indicator for non-Hispanic white race/ethnicity. Approximate 95% pointwise confidence intervals for the curve are given (**dashed lines**), and the "rug" at the base of the figure shows the frequency distribution of travel distances.

from corresponding ZIP code centroids. We also believe that calculating travel distances by assuming treatment at the nearest radiation-treatment facility did not introduce a serious misclassification error into our analysis. The small number of treatment facilities (n = 12) and the relatively large distances between major population centers in New Mexico likely mean that most patients receive radiotherapy as close to home as possible.

A number of factors may influence the observed association between travel distance and radiation treatment, including socioeconomic status, type of health care insurance, and regional practice patterns. Such factors were not examined in this study and warrant further investigation. Our observation that travel distance did not influence whether a patient received BCS or whether she received mastectomy suggests that little geographic variation in practice style in the use of adjuvant radiotherapy occurs in New Mexico. We are currently conducting a survey of New Mexico women treated only with BCS for early-stage breast cancer to gain insight into why they did not receive adjuvant radiation therapy. Results from our ongoing study should assist in the interpretation of the findings reported here.

## References


*(1)* NIH consensus conference. Treatment of early-stage breast cancer. JAMA 1991;265:391–5.

*(2)* Goldhirsch A, Glick JH, Gelber RD, Senn HJ. Meeting highlights: International Consensus Panel on the Treatment of Primary Breast Cancer. J Natl Cancer Inst 1998;90:1601–8.

*(3)* Mann BA, Samet JM, Hunt WC, Key CR, Goodwin JM, Goodwin JS. Changing treatment of breast cancer in New Mexico from 1969 through 1985. JAMA 1988;259:3413–7.

*(4)* Lazovich DA, White E, Thomas DB, Moe RE. Underutilization of breast-conserving surgery and radiation therapy for women with stage I and II breast cancer. JAMA 1991;266:3433–8.

*(5)* Young WW, Marks SM, Kohler SA, Hsu AY. Dissemination of clinical results. Mastectomy versus lumpectomy and radiation therapy. Med Care 1996;34:1003–17.

*(6)* Ballard-Barbash R, Potosky AL, Harlan LC, Nayfield SG, Kessler LG. Factors associated with surgical and radiation therapy for early stage breast cancer in older women. J Natl Cancer Inst 1996;88:716–26.

*(7)* Joslyn SA. Radiation therapy and patient age in the survival from early-stage breast cancer. Int J Radiat Oncol Biol Phys 1999;44:821–6.

*(8)* Farrow DC, Hunt WC, Samet JM. Geographic variation in the treatment of localized breast cancer. N Engl J Med 1992;326:1097–101.

*(9)* Riley GF, Potosky AL, Klabunde CN, Warren JL, Ballard-Barbash R. Stage at diagnosis and treatment patterns among older women with breast cancer: an HMO and fee-for-service comparison. JAMA 1999;281:720–6.

*(10)* Shambaugh EM, Weiss MA, editors. Summary Staging Guide: Cancer Surveillance, Epidemiology, and End Results (SEER) Program. Bethesda (MD): U.S. Department of Health, Education, and Welfare, National Institutes of Health: NIH Publ No. 86-2313; 1977.

*(11)* Hastie TJ, Tibshirani RJ. Generalized Additive Models in Monograph on Statistics and Applied Probability No. 43. London (U.K.): Chapman & Hall; 1990.

*(12)* S-PLUS 4 guide to statistics. Seattle (WA): Data Analysis Products Division, MathSoft; 1997.


## Notes

[1]*Editor's note:* SEER is a set of geographically defined, population-based, central cancer registries in the United States, operated by local nonprofit organizations under contract to the National Cancer Institute (NCI). Registry data are submitted electronically without personal identifiers to the NCI on a biannual basis, and the NCI makes the data available to the public for scientific research.


Supported by Public Health Service contract N01PC67007 from the National Cancer Institute, National Institutes of Health, Department of Health and Human Services.

Manuscript received July 30, 1999; revised November 17, 1999; accepted November 30, 1999.