Driving Performance in Patients With Cancer in the Head and Neck Region

A Pilot Study

Hon K. Yuen, PhD, OTR/L; M. Boyd Gillespie, MD; Russell A. Barkley, PhD; Terry A. Day, MD; Dipankar Bandyopadhyay, PhD; Anand K. Sharma, MD

Objective: To investigate actual driving performance in a group of patients with cancer in the head and neck region.

Design: A nonrandomized controlled trial.

Participants: Ten patients with cancer in the head and neck region participated in a driving evaluation using a virtual reality driving simulator. Driving performance from the simulator and observer ratings on participants’ driving behaviors were compared between a group of patients with cancer in the head and neck region and a group of 50 community control subjects.

Main Outcome Measures: Average speed, mean brake reaction time, steering variability, the total number of (fatal and nonfatal) collisions during the 12-minute evaluation course on the driving simulator, and the score of the 18-item Simulator Driving Performance Scale.

Results: Using Mann-Whitney U tests, the brake reaction time and the steering variability in the cancer group were significantly longer and larger, respectively, than those in the control group ($P = .04$) and ($P = .02$). However, no significant differences were found between the 2 groups in the mean rank scores for average speed, total number of collisions, and Simulator Driving Performance Scale ($P > .05$ for all).

Conclusions: This pilot study provides preliminary evidence indicating inferior driving performance in a group of patients with cancer in the head and neck region when compared with a community control group. Further study is needed to investigate factors attributing to the difference.

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Driving is a complex task that requires adequate cognitive, psychomotor, and visuoperceptual-motor functions that work together. These functions can be compromised to a greater or lesser extent in patients with cancer in the head and neck region who have received cancer treatment. Reduced head and neck mobility, cognitive impairment, pain, and psychological distress, as side effects from cancer treatment, may predispose these patients toward greater driving risks and adverse outcomes. However, the impact of these dysfunctions on the activities of daily living, such as driving a motor vehicle, is not well established.

Yuen et al surveyed the driving behaviors of 83 patients with head and neck cancer. They found that more than two-thirds of respondents drove less or stopped driving during cancer therapy and that more than one-fourth continued to drive less or stopped driving after the completion of cancer therapy. Respondents typically reported greater concern about driving under challenging driving situations after their diagnosis, both during and after cancer therapy, than before their diagnosis. Limited driving after cancer therapy was independently associated with concern about driving under challenging driving situations and perceived impaired cognitive function. Also, the rate of traffic violations and accidents among respondents after cancer therapy was significantly higher than before diagnosis. The results of this survey study provide preliminary evidence of the considerable impact of treatment-related adverse effects on driving behaviors in patients with head and neck cancer.

The present study extended the survey findings and aimed to preliminarily investigate actual driving performance using a virtual reality driving simulator in a group of patients with cancer in the head and neck region. We hypothesized that, compared with community control subjects, patients with cancer will exhibit a significantly inferior driving perfor-
mance while operating a driving simulator and will be inferior in the observer rating of such performance.

**METHODS**

**PARTICIPANTS**

Patients with cancer in the head and neck region were recruited through the Head and Neck Tumor Program at Hollings Cancer Center, Medical University of South Carolina (MUSC), Charleston, to participate in this study. Participants in the community control group were drawn from an existing database collected in central Massachusetts by one of us (R.A.B.). They were recruited through advertisements placed in a regional newspaper. The selection criteria for the community control group were the same as those for the cancer group. All participants met the following entry criteria into the study: (1) chronological age of 18 years or older; (2) composite intelligent quotient score greater than 80 on the Shipley Institute of Living Test; (3) corrected or uncorrected visual acuity of no worse than 20/30 based on a brief vision screening using a Snellings eye chart; (4) possession of a valid state driver’s license; and (5) no evidence of deafness, history of neurological disorder or medical disorder affecting the central nervous system (eg, head trauma with >30 minutes loss of consciousness, epilepsy, or stroke), or psychosis based on participants’ self-report.

Ten patients with cancer in the head and neck region (6 men and 4 women) participated in an objective laboratory evaluation of driving using a state-of-the-art virtual reality driving simulator. Fifty middle-aged community adults (27 men and 23 women) from the existing database served as a comparison. The age range of the participants in the control group selected from the database was based on the lower boundary of the age range of the participants in the cancer group, which was 41 years.

**PROCEDURE**

Patients with cancer in the head and neck region who expressed interest in the study were given a thorough explanation of its procedures and requirements, including length of the session, compensation, and potential risks. Those who met the preliminary inclusion criteria were scheduled for an appointment. When patients arrived at the Driving Performance Laboratory in the Department of Rehabilitation Sciences at MUSC, where the driving assessment was conducted, they were given a verbal overview of the procedure and signed the consent form. A licensed clinical psychologist administered the intelligence and vision screening tests. The participants then completed a brief sociodemographic questionnaire that included information about their driving experience and history. Additional information related to cancer treatment was obtained from the medical records.

Next, qualified participants were given a brief orientation to the driving simulator that included an explanation of the features of the simulator and instructions on operating the various controls of the driving simulator. Participants were instructed to operate the simulator as they would normally drive their own vehicle and to obey all traffic signs and signals along the roadway. The scenarios required participants to deal with those situations that they would frequently encounter while driving in the real world. To minimize the effect that the novelty of the driving simulator might have on performance, participants practiced for 10 to 15 minutes on a training course (in a virtual environment slightly different from the testing environment), where assistance was given by the psychologist if necessary, before completing the evaluation course. The same protocol applied to the community control subjects.

The participants then completed the driving evaluation course. They were monitored for signs of simulator sickness. If any participant experienced serious signs of sickness or physical discomfort, testing was halted. The observer (ie, the psychologist) recorded participants’ safe driving practices while they were engaging in the course. At the end of the course, the observer completed an 18-item Simulator Driving Performance Scale (SDPS) that evaluated how well the participants drove while in the simulator. The observer was trained to supervise participants in operating the simulator and to complete the SDPS in previous studies. The patients with cancer were paid a stipend of $80 for their participation. The study protocol was reviewed and approved by MUSC’s institutional review board.

**VIRTUAL REALITY DRIVING SIMULATOR**

The driving performance was conducted with a virtual reality driving simulator manufactured as a police training simulator (FAAC Inc, Ann Arbor, Michigan). This simulator presents various realistic driving scenarios and measures a number of variables related to driving performance (eg, average speed, reaction time to critical events, steering variation in the roadway, and number of collisions). The simulator consists of a master computer and 5 image generators that control 5 (32-in) television monitors surrounding the driving platform and project a driving world to 220° of the driver’s visual field. This fixed platform module contains a driver’s seat with seat belt, steering wheel with directional signals, dashboard with gear shift, and gas and brake pedals taken from a real automobile (Ford Crown Victoria). The television screens provide actual driving road conditions, roadway sceneries, cross intersections, traffic signs and lights, moving vehicles, and pedestrians in the visual field just as though a real vehicle were being operated. The simulator also provides mock rearview and side view mirrors depicting traffic behind and beside the vehicle that must be considered while the participant is driving (eg, overtaking the driver from the rear). It provides not only virtual reality visual feedback to the driver but also auditory feedback of actual engine, tire, road, and other traffic sounds through a quadrophonic speaker system mounted in the driving module. Kinesthetic feedback is provided through the steering wheel by offering variable resistance during turns on the virtual road surface. It conveys an authentic sensory “feel” to the steering of the vehicle. Road vibration is conveyed using a subwoofer speaker placed on the floor of the vehicle platform, on which drivers rest their left foot. Airflow through the platform is also provided by a fan mounted above the monitors, further creating a more natural feel of driving motion.

A 12-minute standardized driving scenario was created by software engineers (FAAC Inc). Both groups (participants with cancer and community control subjects) were tested using the same driving scenario. On this course, participants had to drive through highway, country, and city environments while following verbal directions (“Take your next right/left turn”) administered by the simulator. The evaluation course contained stop signs, traffic lights, and road hazards. Light traffic occurred around the driver, with buildings, other static objects, and vegetation along the roadway. The participants had to react appropriately to 9 critical events or unpredictable situations in the environment. For example, as a participant approaches a car parked along the shoulder of the road, the car suddenly pulls out into the participant’s path. The participant must react by braking in time to avoid a collision. This simulator and its evaluation course have been used to evaluate driving skills in adults with attention deficits as well as to assess the effects of methylenediamine and alcohol on driving perfor-
DEPENDENT MEASURES

The dependent measures from the driving simulator used here were (1) average speed, (2) mean brake reaction time (in milliseconds) to the 9 critical events, (3) steering variability (ie, standard deviation of vehicle lateral offset from the center of driving lane in inches) recorded every second and averaged across the course, and (4) total number of (fatal and nonfatal) collisions during the 12-minute evaluation course. Participant reaction time to each of the 9 critical events requiring braking was recorded. This time interval started as soon as the critical event was generated on the monitors and was terminated by the participant pressing the brake pedal.

SIMULATOR DRIVING PERFORMANCE SCALE

The 18-item SDPS assesses the participant’s driving behavior and skills in a number of areas, including braking properly at intersections, driving within the speed limit, using mirrors properly, and staying a safe distance from other vehicles. Each item is rated on a 4-point scale (1, not at all; 2, sometimes; 3, often; and 4, very often). A composite mean score was formed from these 18 items, with higher scores reflecting better driving behavior and use of sound driving habits. The internal consistency coefficient (as estimated by Cronbach α) for the 18 items was 0.81. The SDPS has been used in the general population as well as in adults with attention deficits and has been reported to have adequate psychometric properties.

Also, participants rated themselves and were rated by the observer on the degree of simulator sickness experienced after completion of the evaluation course using a 5-point scale (0, not at all; 1, mild; 2, moderate; 3, serious; and 4, could not complete the course). The association between participant rating on the degree of simulator sickness experienced and that of the observer rating in the present sample was 0.76 (Spearman ρ, P < .001).

DATA ANALYSIS

Concerning the brake reaction times recorded by the simulator, there were a few instances in which the participant did not brake at all to the critical event, subsequently either crashing or swerving markedly to avoid the event without ever braking. In these few instances, reaction times were exceptionally long (continuing to be recorded until the next critical event was generated) and were obvious in the distributions. Based on the score distribution of the data, a cutoff of 15 seconds was used to determine participants who did not brake for the events. In these cases, the excessive reaction time was replaced by the highest reaction time (the nearest score below 15 seconds) that could be considered as a brake reaction time to the event (part of the typical distribution of all participants for this event). Using the longest reaction time retained the relatively extreme position of the participant’s reaction time, while permitting the participant to be used in the analysis of these scores. Because no reaction time of any single critical event was of interest in this study, an averaged reaction time across all 9 critical events was computed.

Considering the small sample size of the cancer group and the nonnormal distribution of the number of collisions and steering variability, nonparametric Mann-Whitney U tests were used to compare the 4 dependent measures between the 2 groups. Driving is influenced by a driver’s sensory, perceptual, and cognitive skills, as well as motor capacity, all of which are likely to vary with age, driving experience, health status (degree of simulator sickness), and current medication use. To determine whether these variables ought to be considered as covariates, we searched for significant group differences in the variables using analysis of variance and Fisher exact tests, as appropriate. Subsequent analysis using analysis of covariance was conducted to confirm the findings from the Mann-Whitney tests.

Because of the exploratory nature of the study, no adjustment of P values was conducted for multiple statistical comparisons of the dependent measures. Statistical significance was set at P < .05, and all analyses were performed using SPSS version 12.0 software (SPSS Inc, Chicago, Illinois).

RESULTS

The mean ± SD age was 56.1 ± 8.6 years (age range, 41–66 years) in the cancer group and 48.1 ± 6.1 years (age range, 41–74 years) in the control group. Participants in the cancer group were on average older than those in the control group (P < .001). Regarding the sex distribution, 6 participants in the cancer group (60%) and 27 participants in the control group (54%) were men (not a significant difference). Regarding the racial distribution, 8 participants in the cancer group (80%) and 49 participants in the control group (98%) were white (also not a significant difference). A greater proportion (marginally significant) of the participants in the cancer group took medication compared with those in the control group (P = .08), with 8 participants in the cancer group taking medication compared with 23 in the control group (46%). No significant difference was found between the 2 groups in years of driving experience, weekly driving mileage, and participant or observer rating on the degree of simulator sickness. Comparison of the sociodemographic characteristics between groups is shown in Table 1.

Table 2 shows the treatment-related medical information of the patients with cancer. The median duration between surgery and study participation was 26.6 months. The mean duration between completion of can-
cancer therapy and study participation was 20.0 months. One participant was still undergoing cancer therapy while participating in the study. For adjuvant therapy, patients typically received weekly cisplatin, alone or with paclitaxel, during the 7 weeks of radiation therapy. One patient received 4 cycles of a standard CHOP (cyclophosphamide, doxorubicin, vincristine, and prednisone) regimen, and another received 5 cycles of rituximab (Rituxan).

Using the Mann-Whitney U test, the mean rank scores of brake reaction time and steering variability in the cancer group were significantly longer and larger, respectively, than those in the control group (P = .04) and (P = .02) (Table 3). However, no significant differences were found between the 2 groups in the mean rank scores of the average speed and the total number of collisions (P > .05 for all). Analysis of covariance was used to determine whether the simulator driving skills were different between the 2 groups after adjustment for the differences in age and current medication use. The steering variability was observed to be not normally distributed; a reciprocal (1/x) transformation of this dependent measure was necessary for reducing the effect of skewness. Results of the analysis of covariance indicated that the adjusted brake reaction time to avoid accidents and the steering variability (1/x) in the cancer group were significantly longer and larger, respectively, than those in the control group (P = .03) and (P = .01). One piece of missing data was observed in the mean reaction time owing to mechanical failures of the simulator. However, no significant difference was found between the 2 groups in the adjusted mean scores of the average speed and the total number of collisions (P > .05 for all).

Although the safe driving practices of the participants in the cancer group, as rated by the observer on their performance using the SDPS, were inferior to those in the control group, the difference was not significant (P = .09). The mean ± SD SDPS score was 3.1 ± 0.5 for the cancer group and 3.4 ± 0.4 for the control group. There were 2 participants in the cancer group and 8 participants in the control group who did not finish the 12-minute course because of simulator sickness. The driving behaviors of the 8 participants in the control group were not rated, but the driving behaviors of the 2 participants in the cancer group were rated.

Results of this pilot study show that the participants in the cancer group exhibited slower brake reaction time and more steering variability in a driving simulator than did the participants in the control group. Findings of the analysis after adjustment for the differences in age and current medication use were consistent with those of the nonparametric Mann-Whitney tests. Also, the cancer group showed a trend toward using fewer safe driving behaviors, as rated by the observer, than the control group. Such findings may indicate that patients with cancer in the head and neck region exhibit inferior driving skills compared with community adults and may potentially imply increased risks for various adverse outcomes while driving.

Despite these differences (brake reaction time and steering variability), the cancer group did not show significantly more collisions in the driving simulator than the

<p>| Table 2. Treatment-Related Medical Information in the Cancer Group |</p>
<table>
<thead>
<tr>
<th>Patient No./ Sex/Age, y</th>
<th>Cancer Stage</th>
<th>Cancer Type</th>
<th>Tumor Site</th>
<th>Surgery</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/43</td>
<td>T3N0M0</td>
<td>Chondrosarcoma</td>
<td>Larynx</td>
<td>Laryngectomy</td>
<td>None</td>
</tr>
<tr>
<td>2/F/58</td>
<td>1A</td>
<td>Diffused large B-cell non-Hodgkin lymphoma</td>
<td>Neck</td>
<td>None</td>
<td>Chemoradiation</td>
</tr>
<tr>
<td>3/M/54</td>
<td>TxN2bM0</td>
<td>SCCA (neck)</td>
<td>R neck</td>
<td>R neck dissection</td>
<td>Radiation</td>
</tr>
<tr>
<td>4/M/66</td>
<td>T2N2c (tonsil), T1 (epiglottis)</td>
<td>SCCA (tonsil) and T1 (epiglottis)</td>
<td>R tonsil and epiglottis</td>
<td>None</td>
<td>Chemoradiation</td>
</tr>
<tr>
<td>5/F/64</td>
<td>TxN2aM0</td>
<td>Poorly differentiated carcinoma</td>
<td>L neck</td>
<td>L neck dissection</td>
<td>Radiation</td>
</tr>
<tr>
<td>6/M/54</td>
<td>T1N2bM0</td>
<td>SCCA (nasopharynx)</td>
<td>Nasopharynx</td>
<td>None</td>
<td>Chemoradiation</td>
</tr>
<tr>
<td>7/M/41</td>
<td>T1N0M0</td>
<td>SCCA (tongue)</td>
<td>R tongue</td>
<td>R neck dissection and partial glossectomy</td>
<td>Radiation</td>
</tr>
<tr>
<td>8/F/57</td>
<td>TxN2cM0</td>
<td>SCCA (neck)</td>
<td>Neck metastasis</td>
<td>Bilateral neck dissection</td>
<td>Radiation</td>
</tr>
<tr>
<td>9/M/59</td>
<td>1A</td>
<td>Diffused large B-cell non-Hodgkin’s lymphoma</td>
<td>L neck</td>
<td>None</td>
<td>Chemoradiation</td>
</tr>
<tr>
<td>10/M/65</td>
<td>T2N1Mx</td>
<td>SCCA (tongil)</td>
<td>R tonsil</td>
<td>None</td>
<td>Chemoradiation</td>
</tr>
</tbody>
</table>

Abbreviations: L, left; R, right; SCCA, squamous cell carcinoma.

<p>| Table 3. Comparison of the Driving Simulator–Dependent Measures Between Cancer and Control Groups |</p>
<table>
<thead>
<tr>
<th>Dependent Measures</th>
<th>Group</th>
<th>Mean ± SD</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average speed, mph</td>
<td>Cancer</td>
<td>21.80 ± 6.33</td>
<td>25.18 ± 4.22</td>
</tr>
<tr>
<td>No. of collisions</td>
<td>Cancer</td>
<td>1.10 ± 1.10</td>
<td>1.40 ± 1.25</td>
</tr>
<tr>
<td>Brake RT, ms</td>
<td>Cancer</td>
<td>3194.92 ± 1317.19</td>
<td>2299.83 ± 938.31</td>
</tr>
<tr>
<td>Steering variability</td>
<td>Cancer</td>
<td>271.26 ± 414.33</td>
<td>46.45 ± 25.93</td>
</tr>
</tbody>
</table>

Abbreviation: RT, reaction time.

COMMENT

Although the safe driving practices of the participants in the cancer group, as rated by the observer on their performance using the SDPS, were inferior to those in the control group, the difference was not significant (P = .09). The mean ± SD SDPS score was 3.1 ± 0.5 for the cancer group and 3.4 ± 0.4 for the control group. There were 2 participants in the cancer group and 8 participants in the control group who did not finish the 12-minute course because of simulator sickness. The driving behaviors of the 8 participants in the control group were not rated, but the driving behaviors of the 2 participants in the cancer group were rated.
control group. This lack of significant difference in the number of collisions may be attributable to the 12-minute driving course, which provided just 9 critical events and may not have representatively captured all of the complex factors that could have contributed to differential rates of accidents between cancer and control groups. All scenarios used in this study were set in the daytime, with dry-pavement driving conditions and good visibility. Road conditions that demand a higher level of driving skill, such as during inclement weather or nighttime, and driving under more naturalistic and distracting conditions (conditions that have ecological validity), including the use of cell phones and inattention while adjusting the fan setting or finding a particular radio channel, may better differentiate the accident rate between the 2 groups.

Because the present study is preliminary, a sample size calculation was conducted to estimate the ideal number of participants for the design of similar future studies. With the underlying normality assumptions for the 2 key dependent measures (brake reaction time and steering variability), sample size calculations were based on 2-sided t-tests after a type I error rate of 0.05 was controlled for. We calculated that a sample size of 75 individuals (15 cancer participants and 60 control subjects, with a ratio of 1:4, accounting for 4 controls per case) will provide 80% power to detect a standardized effect of 0.85 for brake reaction time. For steering variability, a much smaller sample size (6 cancer participants and 24 controls) will provide 80% power to detect a standardized effect of 1.36.

While the results of this study suggest that patients with cancer in the head and neck region demonstrate inferior driving abilities when compared with community control subjects, the findings must be considered in light of several limitations of the study. First, it should be noted that the historic community control subjects were quite different from the patients with cancer in terms of age, current medication use, socioeconomic status, and geographic location. Although we controlled statistically for current medication use (yes/no) in our analyses, medication effects that are nonlinear in nature may not have been controlled for. Also, a greater number of patients with cancer who are using medications may indicate more comorbid conditions and poorer health, which can affect driving performance. Furthermore, a significantly higher percentage of patients with cancer were from a lower socioeconomic background, and these individuals may not own a car or may regularly use public transportation. As a result, less experience and frequency of driving before cancer treatment may have had an influence on the performance on the simulator. Second, although the observer rating the cancer participants’ safe driving behaviors while operating the driving simulator has been trained and is experienced in completing the SDPS, she was not blinded to the cancer status of the participants. It may not be possible to mask the status of patients who have obvious facial disfigurement, presence of a tracheotomy, or speech impairment due to cancer and surgical treatment. However, the observer was blinded to the driving performance results for the community control subjects.

Finally, this sample represents various types of cancer in the head and neck region, with a variety of treatments, such as surgery and cancer therapy.

The results of this study and our survey¹ on driving behavior among patients with head and neck cancer represent an initial step in the process of understanding driving performance in this population. Since a driving simulator is sensitive enough to distinguish the cancer group from the community control group, these findings provide preliminary evidence to open a new line of research on driving performance among patients with cancer in the head and neck region. However, a larger-scale study, with more rigorous methodological controls, is required to investigate specific causes (eg, cognitive impairment, psychological distress, and head and neck mobility restriction) that can contribute to an inferior driving performance and its implications on driving in the real world among this cancer population. Also, a better-matched cohort of control subjects in several key sociodemographic variables (eg, age, driving experience and frequency, smoking and drinking habits, medication/substance use, chronic medical conditions, and psychological profiles) that are known to relate to driving performance should be selected.

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Correspondence: Hon K. Yuen, PhD, OTR/L, Occupational Therapy Educational Program, College of Health Professions, Medical University of South Carolina, 77 President St, Charleston, SC 29425 (yuen@musc.edu).

Author Contributions: Drs Yuen, Gillespie, and Day had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Yuen, Barkley, and Day. Acquisition of data: Yuen, Gillespie, Barkley, Day, and Sharma. Analysis and interpretation of data: Yuen, Gillespie, Barkley, Day, and Bandyopadhyay. Drafting of the manuscript: Yuen, Barkley, and Bandyopadhyay. Critical revision of the manuscript for important intellectual content: Yuen, Gillespie, Barkley, Day, and Sharma. Statistical analysis: Bandyopadhyay. Obtained funding: Yuen and Barkley. Administrative, technical, and material support: Yuen and Barkley. Study supervision: Yuen, Gillespie, Barkley, Day, and Sharma.

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Additional Contributions: Deborah Anderson, PhD, administered the psychological assessments and provided the driving evaluations; Larissa Morgan, MA, coordinated the study and managed the data; and Jessica Epinette, BS, and Jena Wozniuk, BS, provided data entry.
REFERENCES


