ROLE OF STATE DRIVER LICENSING POLICIES AND PHYSICIAN REPORTING LAWS ON OLDER DRIVER SAFETY

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ROLE OF STATE DRIVER LICENSING POLICIES AND PHYSICIAN REPORTING LAWS ON OLDER DRIVER SAFETY

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This study aimed to determine the effect of state licensing and physician reporting requirements on older driver safety, guided by hypotheses that states with stricter requirements would result in lower fatal crash rates, lower older driver crash hospitalization rates and a lower prevalence of dementia among those hospitalized compared to states with fewer requirements. Three separate studies were performed. The first study used 2004 to 2009 fatal crashes to examine the effect of state requirements on fatal crash incidence rates using Generalized Estimating Equation (GEE) negative binomial regression models. The second study compared 2004 to 2009 crash-related hospitalizations according to state licensing requirements; with hospitalization incidence rates estimated using three GEE negative binomial regression models. The third study examined crash-related hospitalized drivers to estimate the effect of state requirements on the prevalence of dementia using logistic regression models. Vision testing at in person renewals showed consistent association with lower fatal crash rates, lower hospitalization rates and a lower prevalence of dementia among those hospitalized. Vision testing was especially predictive of a lower crash fatality rate among drivers ages 80 to 84 and lower dementia prevalence among hospitalized drivers ages 60 to 69, reaffirming the safety benefits of vision testing. Physician reporting requirements, mandated or legally protected, and length of licensing renewal lacked any independent association with fatal crash rates, crash-hospitalization rates or dementia prevalence.

The public health significance of this research is its finding that more restrictions on driving do not translate in lower crash rates among older drivers. This research informs older drivers, their families, physicians and state agencies on licensing and reporting requirements that provide safety benefits to assist their safety and mobility decisions. It also informs stakeholders on the utility of screening older patient drivers and demonstrates the need for improved physician tools for the assessment of older adult driving safety.

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1.0 INTRODUCTION

1.1 OLDER DRIVERS

1.1.1 Older driver licensing

As of 2009 there were 39,570,590 adults over the age of 65 in the United States (US Census, 2009) with some 32,934,832 licensed to drive representing 15.7 percent of all licensed drivers (FHWA, 2010). Since 2000 there has been an increase of 5.6 million older drivers (FHWA, 2010) or an increase of 20% from 2000 levels (FHWA, 2000). In 2000, only 88% of adults 65 to 69 were licensed to drive, this in contrast to over 94% of the same age group licensed to drive in 2009. This trend is true for the oldest old as well, with 58.2% of those 85 and older licensed to drive in 2009, compared to 48.4% in 2000, an increase of 20.5% (FHWA, 2000, 2010). The increase is especially clear among older women with an increase of some 29% in licensed women drivers over the age of 85 compared to year 2000 (Table 1). Also, as with middle aged adults where the proportion of licensed drivers is equal among genders, some 94% of whom drive, the gender gap in licensed older drivers is expected to wane.

Based on U.S. census bureau estimates, by 2050 there will be some 88.5 million older adults, representing 25% of the driving population, an increase from the current 16.1% of the driving population (US Census, 2009) with more than 80% of older adults expected to be licensed to drive (Vanderbur & Silverstein, 2006).

Table 1: Changes in licensed drivers (2000-2009)

	Male			Female			Total		
Age group	**2000**	**2009**	**% Change**	**2000**	**2009**	**% Change**	**2000**	**2009**	**% Change**
65-69	95.1	99.2	4.41%	1.9	89.6	9.38%	88.0	94.1	6.97%
70-74	93.4	96.5	3.1%	7.2	83.2	7.85%	84.3	89.2	5.83%
75-79	92.6	93.5	0.89%	0.7	76.0	7.44%	79.7	83.5	4.74%
80-84	90.3	89.6	-0.71%	9.6	66.8	12.06%	71.0	75.8	6.79%
85 and over	78.0	83.0	6.41%	6.3	46.8	28.93%	48.4	58.2	20.45%
Source: 2000 and 2009 FHWA License Reports									
http://www.fhwa.dot.gov/ohim/hs00/dl.htm									

1.1.2 Car ownership and travel patterns

As with younger Americans, adults 65 and older rely on personal vehicles for mobility. Studies have shown that older adults conduct some 90% of their travel using a personal vehicle and rely on their personal vehicle for personal transportation as much as younger adults, with public transportation accounting for only 2% of an older adults daily travel (Collia, Sharp, & Giesbrecht, 2003). Those 65 and older make an average of 3.5 vehicle trips per day, lower than the 4.5 average daily trips of the most active driving population, those 25-54 years old (RITA, 2001). While reliant on the personal vehicle, older drivers take fewer long distance trips than younger drivers and have an average of 17 miles per trip, lower than the 35 mile average reported by 25-54 year olds (RITA, 2001).

The purpose of personal vehicle trips changes with age. Drivers 65 and older take less work-related trips and proportionally more trips (93.8%) for family or social and recreational purposes (Pat S. Hu & Reuscher, 2004; Shinar, 2007) with women taking some 20% fewer trips, as drivers, than men (Pat S. Hu & Reuscher, 2004). Furthermore, older adults are driving significantly more than previous generations. In comparison to adults 65 and older in 1990, adults 65 and older in 2001 drove 21.1 Vehicle Miles Traveled (VMT) per person or 42% more miles that the 14.8 VMT per person in 1990. In addition to higher VMT's per person, older drivers in 2001 spend more time driving per day (49.11 minutes vs. 30.83 minutes) made more trips and the trip length was longer than for 65 and older adult drivers in 1990 (Pat S. Hu & Reuscher, 2004).

Older drivers are responsible drivers. Among all drivers involved in crashes in 2006, those over 65 had the lowest proportion of drivers with blood alcohol concentration (BAC) of 0.08 grams per deciliter (g/dL) or higher (NHTSA, 2008). Older drivers are also more likely to use seat belts, with some 76% of all older driver occupants at time of crash using seat belts, in contrast to 62% of younger adults occupants (NHTSA, 2008). Older drivers are generally underrepresented in citations for a number of violations such as not keeping in lane, driving too fast, alcohol or drug use, or reckless driving (Kilgore et al., 2009). As previously noted, there are differences in travel behavior among older drivers and younger ones. Reflecting their tendency to drive on weekdays and during the daytime, some 72% of crashes involving older drivers occur on weekdays and the majority (81%) of crashes during the daytime (NHTSA, 2008).

1.1.3 Older driver crashes, hospitalizations and injuries

Motor-vehicle related deaths and injuries are a significant concern for older adults. In 2007, unintentional injuries, including motor-vehicle related injuries, represented the 9th leading cause of death, 2nd leading cause of injury death and the 4th leading cause of injury for adults 65 and older (CDC, 2011). By 2030 a 155% increase is expected in the number of older drivers and a 180% increase in MV-related injuries (Lyman, Ferguson, Braver, & Williams, 2002b) with significant consequences for future disability. MV-related injuries result in significant post-crash disability, accounting for 25% of limitations in activities of daily living (ADL) among those with injury-related chronic disabilities (Guerrero JL, 1999). This problem is especially concerning for older adults. Since 2001, some 1.4 million older adults have received emergency department (ED) treatment (CDC, 2010) and over 64,000 have died due to motor vehicle (MV) injuries (NHTSA, 2009) and motor-vehicle related hospitalizations and injuries for 2008 alone have resulted in an estimated $3 Billion in direct medical costs (Corso, Finkelstein, Miller, Fiebelkorn, & Zaloshnja, 2006; Naumann, Dellinger, Zaloshnja, Lawrence, & Miller, 2010).

In 2009, some 175,000 adults 65 and older were admitted to emergency departments due to MV related injuries, with another 31,000 further transferred or hospitalized (CDC, 2011). In that same year 4,396 adults 65 and older were killed as drivers of a motor vehicle in-transport (NHTSA, 2011). These motor-vehicle crash and injury trends represent a slight decline from 2008 when some 183,000 adults 65 and older were admitted to emergency departments with 34,000 transferred or hospitalized (CDC, 2010) and 4,640 having died within 30 days of crash (NHTSA, 2009). This decline in motor-vehicle related crashes and hospitalizations has also been observed among younger populations, with some 24,432 deaths reported among drivers and passengers under the age of 65 in 2009, a decline from 27,354 reported in 2008 (NHTSA, 2011).

Furthermore, 2009 had the lowest motor-vehicle fatalities since the 1950's with 33,808 deaths (NHTSA, 2011).

A number of factors are thought to have contributed to this recent decline in motor vehicle crashes. A recent study argued that a combination of large decreases in crashes involving young drivers, multiple-vehicle crashes and crashes occurring during the weekends were responsible for this decline (Longthorne, Subramanian, & Chen, 2010). Furthermore, this study showed an inverse correlation between unemployment among young adults and crashes involving young drivers (Longthorne, et al., 2010). The decline of 19.11% in motor vehicle fatalities from 2007 to 2009 among those under 65 in contrast to an 11.4% decline among older drivers highlights this difference in trends (Table 2).

Table 2: Crash involvement trends

	2007	**2008**	**2009**	**2007-2008 % Change**	**2008-2009 % Change**	**2007-2009 % Change**	**Source**
MV-Crash Fatalities (All Ages)*	41,259	37,423	33,803	-9.30%	-9.67%	-18.07%	(NHTSA, 2011)
MV-Crash Fatalities (65 +)*	5,967	5,561	5,288	-6.80%	-4.91%	-11.38%	(NHTSA, 2011)
MV-Crash Fatalities (Under 65)*	35,170	31,791	28,450	-9.61%	-10.51%	-19.11%	(NHTSA, 2011)
VMT in Billions	3,032	2,974	2,932	-1.91%	-1.41%	-3.30%	(NHTSA, 2011)
Fatalities per100 Million VMT	1.36	1.25	1.13	-8.09%	-9.60%	-16.91%	(NHTSA, 2011)
Non-fatal injuries (WISQARS)	3,212,352	3,115,813	3,192,673	-3.01%	2.47%	-0.61%	(CDC, 2011)
Police-Reported Crashes	6,024,000	5,811,000		-3.54%			(Longthorne, et al., 2010)

*includes pedestrian, motorcyclists and other traffic related deaths

Nevertheless, whether this decline is temporary or permanent, motor vehicle related deaths and injuries represent a significant burden to those injured, their families and society. One area of difficulty has been the quantification of the safety of older drivers. On an absolute number of driver deaths basis, those over the age of 65 represent a relatively small portion of all deaths (Figure 1). Although older drivers contribute few deaths as drivers, some argue that given that older drivers drive less, fewer are licensed to drive and they make up smaller portions of the population, assessments of older driver safety based solely on absolute fatal crashes may be misleading (Loughran, Seabury, & Zakaras, 2007).

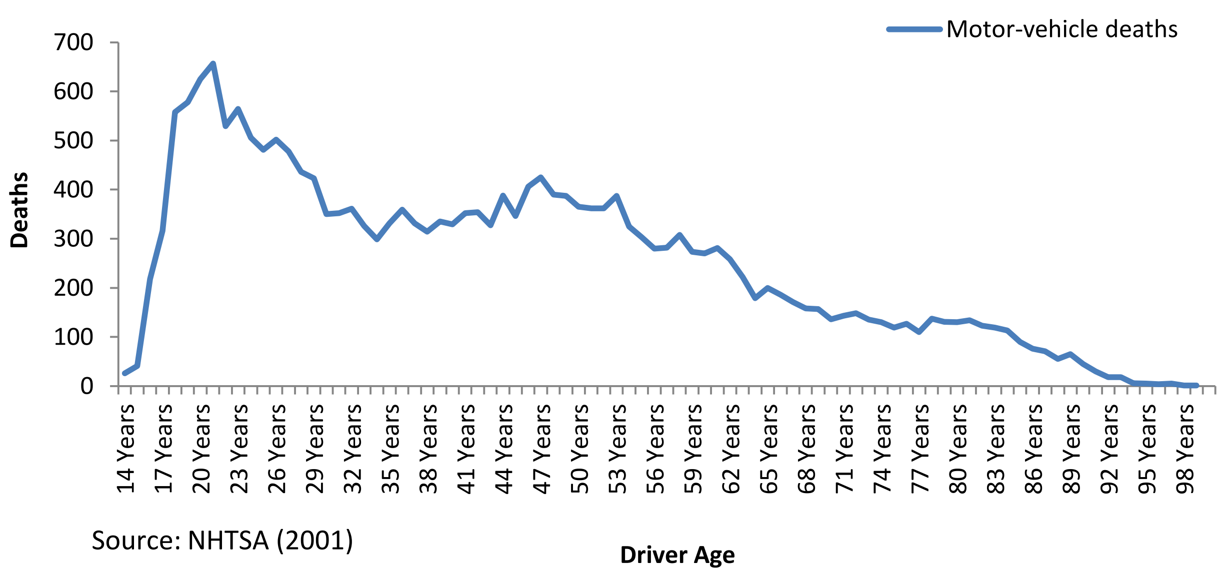

Figure 1: MV driver deaths by age (2009)

Using most recently available motor-vehicle crash fatality data from 2009, on a per licensed driver basis and per person basis, older adults, specifically those over the age of 79 seem to have a higher risk of crash than younger drivers, except those under 20 (Figure 2) (Morrisey &

Grabowski, 2005; NHTSA, 2011). Based on these rates as measures of risk, older drivers, specifically those over the age of 79 may represent a population of drivers at increased risk of MV related deaths. Furthermore, as highlighted by Shinar (2007) the central issue related to older driver safety is their death and injury rate relative to their miles driven. When deaths per VMT are use as the indicator of risk, then older drivers show a significantly higher death and injury rate compared to younger drivers (Loughran, et al., 2007; Shinar, 2007). Similarly, Dillinger et al. (2004) found that on a mile driven basis, young drivers (16 to 19) and older drivers (aged >74) were more likely to cause the death of other road users and young drivers (16 to 19) and older drivers (aged ≥ 85) were more likely to cause the injuries of other road users compared to drivers aged 20 to 74 (Dellinger, Kresnow, White, & Sehgal, 2004).

Contrary to these previous studies, a separate study using data from the Nationwide Personal Transportation Survey (NPTS) to estimate VMT's, concluded that older drivers were not at increased crash risk on a per VMT basis (Kweon & Kockelman, 2003). Similarly, a NHTSA report argued that drivers 65 and older have lower crash involvement rates that drivers aged 21 to 64 (Zeger, Liang, & Albert, 1988). This analysis using crash and license data from 2001 to 2005 reported that in 2005 drivers 65 and older had a crash involvement rate of 21.2 per 100,000 licensed drivers, in contrast to 27.8 for those 21 to 64 (Zeger, et al., 1988). However this grouping assumes homogeneous crash involvement rates within the two groupings, an assumption that may be incorrect.

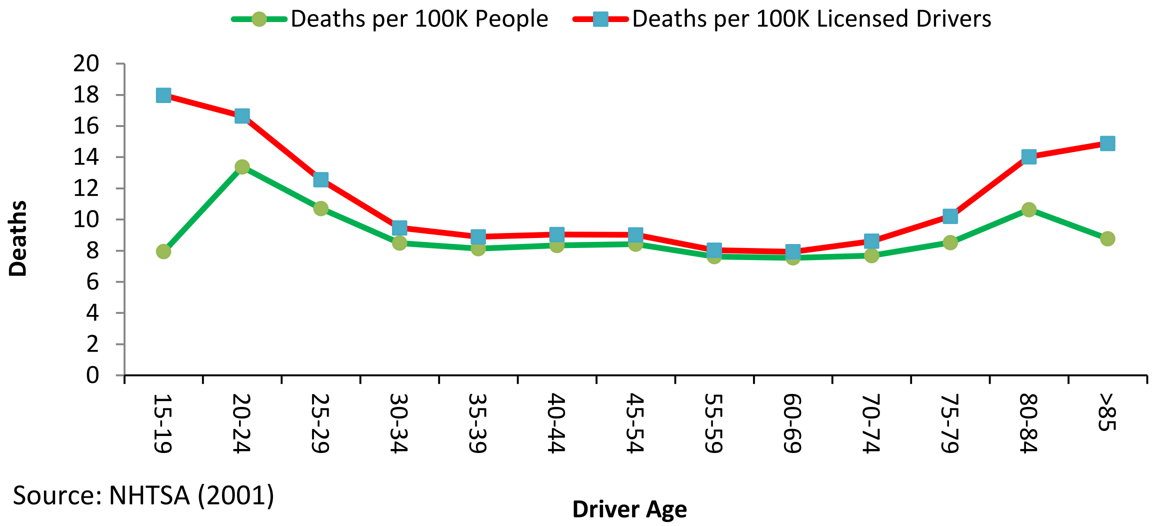

Figure 2: Rate of MV driver deaths by age group in 2009

With regard to crash involvement by any measure of exposure, deaths per population, per licensed drivers or miles driven, drivers 65 to 69 have crash rates similar to those of the younger drivers (Kilgore, et al., 2009; Shinar, 2007). The grouping of those ages 65 to 69 with drivers 70 and older is primarily due to their changes in travel behavior that occur around age 65.

1.1.3.1 Older driver crash characteristics

Older drivers are more likely to be involved in crashes with other vehicles (Kilgore, et al., 2009; NHTSA, 2008), strike stationary objects or stopped or parked vehicles (Kilgore, et al., 2009). Driving maneuvers that require making left turns have been consistently shown to increase crash risk for older drivers (Kilgore, et al., 2009; Mayhew, Simpson, & Ferguson, 2006; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998). One study showed that drivers ages 65 to 69 were 2.3 times the risk for multi-vehicle crash involvements at intersections compared to other situations (Preusser, et al., 1998). Some 32 % of drivers over the age of 80 were involved in multi-vehicle crashes while making left turns, in contrast to 11% for drivers 60-69 (Kilgore, et al., 2009).

Failure to yield to other traffic is another pre-crash scenario continuously identified as a risk factor for older drivers. One study showed that some 39% of drivers 60 to 69, 51% of those 70 to 79 and 62% of drivers 82% and older failed to yield to other traffic (Kilgore, et al., 2009). Similar findings were shown by a number of previous studies (Kilgore, et al., 2009; McGwin & Brown, 1999; Preusser, et al., 1998)

1.1.3.2 Low mileage bias and frailty bias

Further attempting to characterize the crash risk of older drivers, some have argued that even on a per vehicle mile traveled (VMT) the crash rates are not homogenous, as one confounder is the difference in miles driven per person. This has been termed the "low mileage bias" and one study found that when matched to younger drivers with the same travel quantity. only older drivers that drive fewer than 1900 annual miles (3000 km) are at increased risk of a crash (Langford, Methorst, & Hakamies-Blomqvist, 2006). Similarly a previous study showed that when the accidents-per-distance traveled comparison is made between young and older drivers matched for annual amount of driving, there was no evidence for higher risk with increasing age. This study showed that for both the young and older drivers the risk on a per mile traveled basis, declined with age, when adjusting for the amount of driving (T. S. Dee, Grabowski, & Morrisey, 2005).

For studies that examine motor-vehicle related deaths, another potential bias is the inherent susceptibility to injury and death due to age. This bias, termed, frailty or fragility bias argues that age is inversely correlated with trauma survivability. A study by Li et al. (2003) showed that when compared to drivers ages 30-59, those 75 and older had significantly higher death rates per VMT. According to Li et al. only 30-45% of this elevated risk was accounted by the crash over-involvement of drivers of this age group, with 55-70% of the elevated death risk being accounted by fragility (Li, Braver, & Chen, 2003). Similar arguments have been made by Eberhard (1996) as highlighted by Shinar (2007) and Loughran et al. (2007) (Loughran, et al., 2007; Morrisey & Grabowski, 2005; Shinar, 2007).

Older adult drivers tend to limit their driving exposure by limiting driving in riskier conditions such as avoiding driving at night and on highways, as well as avoiding heavy traffic and bad weather. However, their increased fatality rate is thought to be predominantly due to their increased crash rate per vehicle miles driven as well as their disproportional risk of dying in the event that a crash occurs (Lyman, Ferguson, Braver, & Williams, 2002a; Shinar, 2007; Wang & Carr, 2004). It is projected that there will be a considerable increase in the proportion of older driver fatalities and injuries in motor vehicle crashes in the coming decades due to substantial changes in the driving demographics (Lyman, et al., 2002a; Shinar, 2007; Staplin, Lococo, Gish, & Decina, 2003). By 2030, it is estimated that one in five Americans, or approximately 72 million people, will be 65 years or older, will live longer than previous generations and approximately 80% of the older adult population in 2030 will be driving (He, Sengupta, Velkoff, & DeBarros, 2005).

1.2 OLDER DRIVER PHYSICAL AND COGNITIVE PERFORMANCE

1.2.1 Cognition and driving

The cognitive functioning of older adults and its impact on driving has received considerable attention. Initially, studies reported that drivers with dementia of the Alzheimer's type (AD) report declines in attention performance, especially when switching between targets for visual selective attention. These types of declines in information-processing tasks related to attention are shown to be related to motor-vehicle crash rates (Parasuraman & Nestor, 1991). Others further reported that older drivers with mild to severe Alzheimer's disease (AD) differed from study controls in driving exam performance and were deemed as unsafe drivers (Hunt, Morris, Edwards, & Wilson, 1993). Subsequently, in a study by Tuokko et al. (1995) adult drivers with dementia were found to have 2.5 times the motor vehicle crash risk of their matched controls (Tuokko, Tallman, Beattie, Cooper, & Weir, 1995). Similarly a matched case-control study by Drachman et al., (1993) reported that drivers with AD had twice the annual crash rate than matched controls with an average of 0.09 crashes per year compared to 0.04 crashes per year for study controls (Drachman & Swearer, 1993).

A review of published studies on driving safety of older adults with dementia showed that drivers with probable AD with a Clinical Dementia Rating (CDR) of 0.5 had mildly impaired driving performance. Authors argued that mildly impaired driving performance is within the levels tolerated for other driving groups; hence such driving performance provides no ground for driving restrictions. Furthermore, this review noted that it was drivers with AD and a CDR of 1 that presented significant safety concerns due to both their poor driving performance and their crash history (Dubinsky, Stein, & Lyons, 2000). These conclusions were further supported by a longitudinal study of driving performance of older drivers with dementia by Duchek et al. (2003). Duchek concluded that those with a CDR rating of 1 received an unsafe driving performance rating much earlier than those with a CDR score of 0 or 0.5 (Duchek et al., 2003). Other studies have provided additional support with a recent study by Ott et al. (2008) reporting that drivers with AD experienced a higher number of accidents and performed worse on road tests than controls. Furthermore, the driving performance of those with AD declines quicker than study controls (Ott et al., 2008).

While a number of studies concluded that mild to severe AD resulted in poorer driving performance, others examined drivers with very mild AD and mild cognitive impairments such as those with traumatic brain injuries (TBI). A study by Wadley and colleagues (2009) showed that drivers with mild cognitive impairments (MCI) showed significantly lower driving performance when compared to controls on various driving maneuvers. However this study also concluded that the poor performance of MCI drivers would not amount to a driving impairment. However, given the likelihood of progression of MCI into dementia, authors argue that drivers with MCI require additional attention for further changes in driving performance (Wadley et al., 2009). Similar conclusions were reached by a study by Berndt and colleagues in 2008. They noted that drivers with negligible dementia were able to pass on-road driving assessments whereas those with moderate dementia failed (Berndt, Clark, & May, 2008).

1.2.2 Crash involvement and cognitive functioning

Because 72% of older driver crashes involved another vehicle (NHTSA, 2008) the age of drivers responsible for crashes has received considerable attention. Studies using both the Fatality Analysis Reporting System (FARS) and the General Estimates System (GES) reached similar conclusions showing that drivers aged 60 to 69 had a below average crash involvement ratio, denoting a below-average risk of being at fault in a crash. However the risk of being at fault in crash was 1.75 for those 70-79 and increased to 4 times the risk of being at fault in a crash for those over the age of 80 (Kilgore, et al., 2009). Similar conclusions were reached by a number of other studies which also argue that this may be due to driving errors such as failure to yield the right of way, failure to notice or regard traffic sign or signal, or poor maneuvering (Mayhew, et al., 2006; McGwin & Brown, 1999).

Crash culpability has been long associated with decline in physical and cognitive performance among older drivers (C. Owsley, 1994; Sagberg, 2006; Uc, Rizzo, Anderson, Shi, & Dawson, 2005). While older people are highly dependent on personal vehicle as a means of transportation (Collia, et al., 2003) older drivers are also at greater risk of experiencing decreased physical and cognitive performance needed to drive safely (Edwards, Perkins, Ross, & Reynolds, 2009; C. Owsley & Ball, 1993; C. Owsley & McGwin, 1999; Zhang et al., 2007). These functional capabilities include visual abilities needed to detect hazards (C. Owsley, 1994), perceptual skills needed to accurately judge traffic gaps and patterns (Zhang, et al., 2007), as well as cognitive functions required to make rapid and appropriate maneuvering decisions (Duchek, Hunt, Ball, Buckles, & Morris, 1998). Physical abilities, such as head and neck flexibility are also required to scan the flow of traffic, before changing lanes, making turns as well as merging with traffic (Staplin, et al., 2003).

Furthermore, while older drivers are not aggressive drivers, they are at an increased crash risk by driving slower than traffic and by misjudging the speed and distance of other vehicles (NCHRP, 2005). And while, as noted previously, older drivers use seat belts more often than other drivers and are less likely to drive under the influence of alcohol (NHTSA, 2008) they are more likely to experience chronic health conditions and to use over-the-counter and prescription drugs, potentially making them less aware of their surroundings (Derouesne et al., 1999; Okonkwo et al., 2009).

Although studies show that age is strongly correlated with declining skills needed for safe driving, age in itself is a poor predictor of safe driving performance, and is therefore not considered an independent criterion for safety measures, such as withholding driver's licenses (Grabowski, Campbell, & Morrisey, 2004a). The extent aging related functional declines impact driving related tasks differs significantly among older drivers (Loughran, et al., 2007). For example, while studies have demonstrated the high correlation between Mini Mental State Examination cognitive performance (MMSE) scores and on-road driving performance (Fitten et al., 1995; Odenheimer et al., 1994) others have demonstrated the low predictive value of MMSE scores on crashes (Morrisey, Grabowski, Dee, & Campbell, 2006; O'Neill, 2007; O'Neill et al., 1992).

1.3 APPROACHES TO OLDER DRIVER SAFETY

Stressing age-related declines in physical and cognitive performance required for safe driving, a number of approaches to the safe mobility of older adults have been applied. The most common approaches include reliance on driver self-regulation, mandated driver assessment and testing, including mandated driver training or re-licensing as well as driver cessation.

1.3.1 Driving self-regulation and driving cessation

Studies indicate that the presence of visual, motor and some cognitive deficiencies is related to driving cessation for older adults (Ackerman, Edwards, Ross, Ball, & Lunsman, 2008; Lafont, Laumon, Helmer, Dartigues, & Fabrigoule, 2008a; Sims, Ahmed, Sawyer, & Allman, 2007). Considerable effort has been put into developing measures to screen older drivers for such deficiencies in order to limit the driving of those with significant health-related functional deficiencies (Lafont, Laumon, Helmer, Dartigues, & Fabrigoule, 2008b; Lundberg et al., 1997; Meuser, Carr, Berg-Weger, Niewoehner, & Morris, 2006; Molnar et al., 2007). However because older drivers are more likely to become aware of their visual and motor deficiencies than cognitive deficiencies or impairments, they may continue driving despite declining cognitive capacities (Daigneault, Joly, & Frigon, 2002; Lafont, et al., 2008b; C. Owsley, Stalvey, Wells, & Sloane, 1999). Data from the U.S. Department of Transportation, Household Transportation Survey shows that with age, older adults self-regulate their driving by reducing their Vehicle Miles Traveled (VMT) a measure of miles traveled, by making fewer short daily trips as well as fewer trips over 50 miles. The trend of decreasing exposure is comparable for men and women drivers, and the data indicates that drivers over 75 years old take 55% fewer trips when compared to drivers 55-64 year old (Collia, et al., 2003; Shinar, 2007).

A person's physical fitness has been shown to be one factor that forces older drivers to regulate their driving, or to stop driving altogether. As shown in a study by Sims et al. (2007) older drivers with low scores on the Self-Reported Health (SRH) measure were twice as likely to report driving cessation after two years of follow up compared to older drivers with high SRH scores (Sims, et al., 2007). Older driver's that do not stop driving completely, change their driving habits by placing restrictions on their driving. The most common driving restrictions include avoiding rush hour traffic, night driving, and to a lesser extend avoiding inclement weather driving on unfamiliar roads, and maneuvers such as left-hand turns (NCHRP, 2005; Staplin, et al., 2003).

Cognitive performance is yet another indicator of driving self-regulation as shown in a study by Freund et al. (2008). The study showed that older drivers that applied driving restrictions performed worse in cognitive measures (Trail-making B) compared to drivers deemed safe by the study (Freund & Colgrove, 2008). In addition, Foley et al. (2000) found in a retrospective study that the majority of drivers with poor cognitive performance but no clinical dementia reported to be driving, in contrast to only 22% of those diagnosed with mild dementia (based on the Clinical Dementia Rating) (Foley, Masaki, Ross, & White, 2000; Lafont, et al., 2008b). In addition to the important role of family members in monitoring driver's safety, one study shows that up to 27% of older drivers stopped driving following recommendations by their physician to do so, significantly higher than the 16% of older drivers who identified their family or friends as the reasons for driving cessation (Persson, 1993).

With regard to driver's self-assessment as pre-conditions for driving self-regulation or cessation, studies show that drivers overall tend to overestimate their driving competence, and older drivers specifically tend to consider themselves "a lot better" than the average driver of the same age, even when simulator-based driving assessments considered their driving performance as "unsafe" (Freund, Colgrove, Burke, & McLeod, 2005). Older drivers also may not have a valid and accurate appreciation of the specific situations in which they are at increased risk, which in turn impacts the type and extent of their self-imposed driving restrictions. This is shown in a study by Baldock et al. (2006) comparing responses on a questionnaire about driving habits and attitudes to their actual driving ability, as measured by an on-road driving test. Results showed that poorer performance on the driving test was not related to the older driver's overall avoidance of difficult situations. This result highlights the discrepancy between their self-reported driving skills and their actual driving performance and driving avoidance (Baldock, Mathias, McLean, & Berndt, 2006).

Even with these limitations, when compared to screening and re-licensing, self-regulation and voluntary driving cessation are considered to be the most desirable means for maintaining the safety of older drivers (Charlton, 2003; Shinar, 2007). However, policies relying on driving self-regulation to maintain the safety of drivers, assume that the drivers, regardless of age, cognitive or physical fitness, appropriately assesses their crash involvement risk, the risks posed by their driving environment, their exposure to this environment as well as make suitable behavioral adaptations to maintain their safety.

1.3.2 Driving self-regulation and driving cessation among special populations

Older adults with various levels of cognitive impairment seem to engage in different levels of driving restrictions, including driving cessation. For example, in a community sample of older adults in Hawaii, some 46% of older drivers with a CDR score of 0.5 indicating very mild dementia reported driving, in contrast to only 22% of those with a mild dementia (CDR=1) and some 5% of those with moderate or severe dementia (CDR>1) (Foley, et al., 2000). Others show that drivers with AD also limit their driving. They engage in driving restriction such as avoiding driving at night, during bad weather, in unfamiliar routes or long distances. Some also avoid driving in heavy traffic, drive at slower speeds and sometimes drive with a co-pilot (Cotrell & Wild, 1999). For those older drivers with a diagnosis of very mild AD, driving is often not eliminated, but authors highlight that the role of family members in monitoring and managing the driving of drivers with AD is critical (Perkinson et al., 2005).

As a contrast to the studies above, Wood et al (2004) showed that there were wide discrepancies between the driving ratings of drivers with Parkinson's disease, as measured by licensing examiners and the older driver's rating of their driving performance. Wood also showed that driving performance of those with Parkinson correlated poorly with the patient's disease severity based on non-psychometric test, clinical scales, indicating the lack of validated instrumentation available to physicians for older driver assessment (Wood, Worringham, Kerr et al., 2004). Therefore, while drivers may engage in driving regulation their assessment of their driving performance may be inaccurate. Furthermore, physicians lack standardized and validated tools to aid in that process.

1.3.3 Theoretical foundations of driving cessation and regulation

While studies have analyzed the relationship between older driver's driving self-regulation, cognitive and physical performance, few studies have explored the process through which older drivers limit their exposure through driving restrictions, assess their risk, or the process through which they decide to cease driving. The Social Cognitive Theory (SCT) has been successfully used in studying driving behaviors in high risk populations such as young drivers (Greening & Stoppelbein, 2000; Wells-Parker, Kenne, Spratke, & Williams, 2000) and older drivers (Stalvey & Owsley, 2003). SCT describes the interaction between perception, environmental factors and personal factors in the adoption of driving behaviors. The SCT is a strong theoretical model that explains the dimensions of behaviors and the influence of environmental and social factors. The SCT stipulates that behaviors are adopted through a learning process influenced by the immediate social and physical environment and by personal factors. A particular strength of SCT is it's differentiation of actual vs. perceived influences of behavior adoption. In a study by Windsor et al. (2008) older drivers with high driving competence, a central SCT concept, reported less avoidance of high-risk driving situations. The study showed that older drivers perceived driving ability was inversely associated with risk avoidance (Windsor, Anstey, & Walker, 2008).

Another theoretical approach to driving cessation argues that patients with reduced cognitive performance, especially those with AD, may engage in restricted driving or driving cessation, dependent on their awareness of their deficit. It further showed that in particular drivers' awareness of their declines in attention was associated with increased driver restrictions such as avoiding unfamiliar routes (Cotrell & Wild, 1999). Furthermore, a recent study on driving regulation and driving cessation uses the rational choice theory, often used in examining social and economic behavior, arguing that an individual acts to balance cost and benefit and maximize personal gain (Scott, 2011). With regard to older drivers, the framework argues that by self-regulation and restricting driving, older adults seek to maximize the benefits of driving, as part of the balance of costs and benefits (Kulikov, 2011a). This study showed that drivers seek to maintain independence and licensing regulations such as accelerated renewal, cognitive testing, and vision testing and in-person renewal significantly impact older driver's decision to reduce or stop driving (Kulikov, 2011a).

Studies exploring the driving behaviors of older drivers have also attempted to design behavioral interventions and educational curricula for older drivers. Stalvey et al. (2003) emphasized the underlying theoretical framework (Social Cognitive Theory), on driver's self-regulatory skills, as well as highlighting the self-efficacy concept (driver's perceived level of confidence in their ability to practice a safe driving behavior). The study reports that their intervention, based on Social Cognitive Theory (SCT), improved older driver study participant's self-perception of vision impairment increased their frequency of high risk situation avoidance and increased their frequency of performing self-regulatory practices (Stalvey & Owsley, 2003). Similar findings were reported by Owsley and colleagues (2003) in their education intervention, which showed that drivers that received an educational intervention that promotes self-regulatory practices, were more likely to acknowledge deficiencies in their vision, report a higher frequency of avoiding high risk driving maneuvers (C. Owsley, Stalvey, & Phillips, 2003).

The Social Cognitive Theory has also been used in measuring the perception of young drivers with regard to risky driving behaviors such as speeding and drinking and driving (Farrow & Brissing, 1990; Greening & Stoppelbein, 2000; Newcomb, Rabow, Hernandez, & Monto, 1997; Shore & Compton, 2000). In a study of young driver's health attitudes, young drivers who perceived rewards for drinking and driving were significantly more likely to report intentions to drink and drive. Additionally young driver's low self-efficacy, a SCT concept indicating their perceived level of confidence in their ability to practice safe driving behaviors, contributed to their intention of drinking and driving (Greening & Stoppelbein, 2000).

1.3.4 Driver licensing in the United States

It is clear that balancing the mobility and independence needs of older adults and ensuring their and the public's safety is a complex undertaking, with shared responsibilities between state governments, physicians, families and driver's themselves. And the complexity of regulatory issues is shown by the wide variation in state legislations and reporting requirements.

Driving licensing in the United States is administered by a number of state institutions, often varying from state to state. For example, in Arizona driver licensing is administered by the Motor Vehicle Division (MVD) of the state's Department of Transportation, in New Mexico it is administered by the MVD housed in the Department of Taxation and Revenue, whereas in Alabama it is administered by the state's Department of Public Safety. Additionally, a number of state driver licensing institutions also receive consultations by members of state's Medical Advisory Board (MAB) (TransAnalytics, 2003). These MAB members, in addition to reviewing fitness to drive of referred cases, have other consulting duties to driver licensing bodies, which often include advising on medical criteria and vision standards for licensing (TransAnalytics, 2003).

The relationship between state licensing institutions and MABs differs from state to state. In a number of states such as Alabama, MAB members are voluntary consultants to the state's licensing body, while in other states MAB members carry salaries. On a case-by-case basis Alabama's MAB reviews and provides recommendations on the driving eligibility of those with medication condition referred to the board for recommendation. The sources of referral are varying from state to state, but may include physicians, police officers, family members or friends. Often MAB's require that referral sources be named and a sworn affidavit be produced. In a number of states referral to MAB's by physicians is not required, but some states such as Arizona, provide legal immunity to voluntary referring physicians (TransAnalytics, 2003).

In a number of states the recommendations provided by MABs to state driver licensing bodies are closely followed, with final decision resting with the state driver licensing institution (TransAnalytics, 2003) with the extent of such recommendations differing from state to state. In states such as Connecticut, upon review of recommended driver, the MAB may conclude that there is no evidence of any medical condition that would adversely affect the driver's ability to safely operate vehicle or recommend that the person should not operate vehicle due to person's medical condition. Furthermore, other recommendations include that person undergo driving reevaluation by the driver licensing institution or that the person be allowed to operate vehicle under specified conditions such as hour of day, types of roads or undergo further medical examinations. In Connecticut, some 75% of MAB recommended cases involve a driver over the age of 64 of which some 20% are required to undergo a driving re-evaluation (TransAnalytics, 2003).

In a review of licensing requirements across the United States, the Insurance Institute for Highway Safety (IIHS) reported that there are significant differences in various licensure provisions between States in the US (IIHS, 2011a). The most frequent licensing regulations that vary by state include the drivers license renewal cycle for older drivers, frequently for those over the age of 64, vision test requirements, the requirement that drivers present in-person at licensing institution for drivers license renewal, requirements for written or road tests as well as self or physician reports on driver's medication condition. One of the most controversial requirements, in-person appearance for renewal, is designed to allow DMV personnel to visually evaluate applicants. For example, older drivers in Louisiana have a 4 year renewal cycle, with in-person renewal for those above 70 (AAA, 2011; IIHS, 2011a) whereas older drivers in Florida renew their license every 8 years and pass a vision test, but are required to attend in-person renewals only every 16 years (AAA, 2011; AMA, 2010)

The information below highlights the main types of age-based driver's licensing restrictions available across the US. The information below is from the AAA Foundation for

Traffic Safety database on US and Canada driver licensing policies and practices and the Insurance Institute for Highway Safety Older driver program (AAA, 2011; IIHS, 2011b).

Renewal Cycle: Accelerated renewal cycle for older drivers is required in 19 (37%) of states and the District of Columbia. The length of accelerated renewal differs widely between states, from every 1 year for the drivers 75 and older in New Mexico, to every 2 years for drivers older than 85 in Iowa.

Testing requirements: Visual field testing is required in 23 states and DC and 43 states and DC require visual acuity testing. The age at which testing is required differs between states, with some states such as Florida requiring visual acuity testing at age 81 or older and others such as Oregon requiring testing starting at age 51.

In-person renewal: The majority of states and the DC have an in-person renewal requirement of all their drivers or only their older drivers. Some 36 states and DC (70%) require drivers to present in-person at licensing locations for license renewal that may not require any testing. In-person renewals also differ between states, with states such as Texas requiring drivers to present in-person only starting at age 80, whereas those in Maine are required to present in person at every renewal past age 63.

Physician reporting or medical reports: The vast majority of states and DC (88%) require that drivers alert the licensing office of any medical conditions that may impair their driving. However, only 7 of the states require physicians to report at-risk drivers, but all states permit physicians in doing so and 32 of the states provide legal protection to referring physician. Table 2 below highlights main driver's licensing requirements for a select number of states from IIHS and AAA Foundation driver licensing policies and practices database (IIHS, 2011; AAAF, 2011).

Table 3: Licensing Requirements for Older Drivers

	Mandatory Physician Reporting	Legally Protected Reporting	In-person renewal	Vision testing at renewal	Road Testing
Arizona		2004-09	2004-09	2004-09	
Arkansas			2004-09	2004-09	
California	2004-2009	2004-09		2004-09	
Colorado		2004-09	2004-09	2004-09	
Connecticut		2004-09	2004-09		
Florida		2004-09	2004-09	2004-09	
Georgia			2004-09	2004-09	
Hawaii			2004-09	2004-09	
Illinois		2004-09	2004-09	2004-09	2004-09
Indiana		2004-09	2004-09	2004-09	
Iowa		2004-09	2004-09	2004-09	
Kansas		2004-09	2004-09	2004-09	
Kentucky		2004-09	2004-09		
Louisiana		2008-09	2008-09	2008-09	
Maine		2006-09	2006-09	2006-09	
Maryland				2004-09	
Massachusetts			2004-09	2004-09	
Michigan			2004-09	2004-09	
Minnesota		2004-09	2004-09	2004-09	
Missouri		2004-09	2004-09	2004-09	
Montana		2009	2009	2009	
Nebraska			2004-09	2004-09	
Nevada			2004-09	2004-09	
New Hampshire			2004-09	2004-09	2004-09
New Jersey		2004-09	2004-09		
New Mexico		2009	2009	2009	
New York				2004-09	
North Carolina		2004-09	2004-09	2004-09	
Ohio			2004-09	2004-09	
Oklahoma		2005-09	2005-09		
Oregon	2004-07, 09	2004-07, 09	2004-07, 09	2004-07, 09	
Pennsylvania	2009	2009			
Rhode Island		2004-07, 09	2004-07, 09	2004-07, 09	
South Carolina		2004-07, 09		2004-07, 09	
South Dakota			2004-07, 09	2004-07, 09	
Tennessee			2004-07, 09		
Texas		2004-07, 09	2004-07, 09	2004-07, 09	
Utah		2004-07, 09	2004-07, 09	2004-07, 09	
Vermont					

Table 3: Continued

Virginia			2004, 06-07, 09	2004, 06-07, 09	
Washington			2004-09	2004-09	
West Virginia			2004-09		
Wisconsin		2004-09	2004-09	2004-09	
Wyoming			2007-09	2007-09	

1.3.5 Studies on driver screening

The introduction of new licensing requirements has been shown to influence the driving population. A study showed that the introduction of cognitive testing at drivers license renewal centers in the UK significantly increased the number of older drivers recommended to undergo driving tests and significantly decreased the number of driver's license renewals obtained (Hansen, 2002). Although studies show that MMSE scores, as used in the Hansen (2002) study, have low predictive value of for crashes (O'Neill, 1995).

Studies also note that driving performance test passing rates for old drivers are not fully associated with age, indicating that age-based licensing screenings are deemed to have low sensitivity and specificity (Charlton, 2003; Hakamies-Blomqvist, Johansson, & Lundberg, 1996; Loughran, et al., 2007; Shinar, 2007). Furthermore, it is unclear whether differences in licensing provisions result in differences in the incidence of MV crashes as studies have reported conflicting results. Some have reported that licensing provisions such as vision screening requirements result in a reduced MV crash fatality rate (Levy, Vernick, & Howard, 1995; McGwin, Sarrels, Griffin, Owsley, & Rue, 2008). Others report that vision tests, road tests and length of license renewal cycle have no impact on MV crash fatalities (Grabowski, et al., 2004a; Morrisey & Grabowski, 2005). Additionally, one Australian study comparing different licensing jurisdictions showed that even among drivers 80 years of age or older, mandatory assessment programs, as a whole, do not have demonstrable safety benefits in terms of either total fatalities or other road user fatalities (Langford, Bohensky, Koppel, & Newstead, 2008). Similarly, two other Australian studies that compared crash involvement rates on a per population and per licensed driver basis across all Australian states concluded that older drivers in jurisdictions with age-based mandatory licensing were not safer drivers than those from jurisdictions without mandatory licensing requirements (Langford, J., M. Fitzharris, et al., 2004; Langford, J., M. Bohensky, et al. (2008).

Similarly, a review by Charman et al. (1997) argued that although a decline in vision has been associated with increased crash risk, there is no single test or a combination of instruments that effectively screens for those with increased crash risk without leading to the disqualification of large number of safe drivers (Charman, 1997). Similarly, a recent study concluded that the predictive values of commonly used vision tests for licensing are inconclusive as vision test scores do not adequately explain unsafe driving performance (Bohensky, M., J. Charlton, et al., 2008). This is important as studies show that the introduction of barriers to driving is strongly associated with a reduction of driving, even for those that may be fit to drive (Kulikov, 2011a). Similarly restricted driving policies, where drivers are restricted to drive under certain circumstances, promoted driving and are shown to be related to a decrease in driving cessation among older drivers, with cognitive testing being associated with an increase in driving cessation among drivers (Kulikov, 2011a).

A study by Dobss et al., (1998) reported that when comparing the road driving performance of older drivers with significant declines in mental abilities to normal older drivers to expert evaluator rating of drivers from the two groups, significant discrepancies were observed. The study concluded that the conventional evaluator criteria used to determine licensing for new drivers should not be applied to experienced older drivers (A. R. Dobbs, Heller, & Schopflocher, 1998).

Studies by Morrisey and Grabowski (2005) and Grabowski, and Campbell (2004) examined the role of licensure laws on crash rates using the Fatality Analysis Reporting System (FARS). Both studies showed that in-person license renewal was related to a significantly lower fatality rate among drivers 85 years or older. They also showed that stringent state licensure policies such as vision tests, road tests, and more frequent license renewal cycles showed no independent association to decreased fatal crash rates (Grabowski, et al., 2004a; Morrisey & Grabowski, 2005). One drawback of these studies is that both studies rely on FARS data that only capture MV crash related deaths and omits non-fatal crashes, the vast majority of crashes. Also, most crashes among older adults occur at low speeds that are injurious but may not be fatal (NHTSA, 2009) and FARS based analyses completely exclude MV-related injuries that require hospitalization but don't result in death. Furthermore, FARS based analyses cannot determine the difference in underlying medical conditions between older drivers in different states.

1.3.6 Physician reporting laws

The responsibility for the safe mobility and independence of older adults rests with the person, their families, licensing institutions as well as health providers. As adults seek to maintain their independence, they continue driving their personal vehicles. While most healthy older adults are expected to drive well past their 80's, those with physical and medical conditions also drive. Studies show that, when asked, older adults with a diagnosis of very mild AD indicate intent to continue driving, regardless of their current diagnosis. Importantly, those drivers also regarded their family members and physicians as pivotal in monitoring and managing their driving ability

(Perkinson, et al., 2005). However, studies have also showed that older driver's self-assessment or their caregiver's perceptions of driving ability are not good predictors of the older adult's actual driving performance (Hunt, et al., 1993). A review of studies by Dobbs (2002) concluded that physicians would have significant difficulties in identifying older adults with mild to moderate dementia that should not drive (B. M. Dobbs, Carr, & Morris, 2002)

Physician reporting requirements vary considerably and have received little attention from the research community as they bear on MV-related deaths and injuries. This is unfortunate because physicians are in the unique position to screen at risk drivers (K. Snyder & Bloom, 2004) given that older adults make an average of seven physician visits per year (Chun-Ju Hsiao, Donald K. Cherry, & Paul C. Beatty, 2010). The screening potential of physicians in Pennsylvania can be contrasted with screening at licensing offices in Florida that require one in-person visit in 16 years for older drivers. This highlights the stark difference in ability to detect older at risk drivers that can be expected to exist between states with different licensing and physician reporting requirements. Currently seven states require primary care physicians or other caregivers to report potentially unsafe drivers, of which three states have broad definitions of at-risk drivers, twenty-four states permit such disclosure at the physician's discretion, and twenty states have no statutory law at all on the subject (AAA, 2011).

The American Medical Association (AMA) has emphasized that the determination of the inability to drive safely is the responsibility of state departments of motor vehicles, but has also recognized the importance of physician's role in ensuring the safe mobility of their patients (K. Snyder & Bloom, 2004). The AMA encourages physicians to engage in preventive practices with patients such as counseling and physical and cognitive performance assessments and encourages reporting in evident cases of significant impairments (AMA, 2011a). The AMA has adopted a number of policies regarding older drivers such as AMA policy E-2.24 that articulates the physician's responsibility in recognizing impairments in patients' driving ability, policy H-15.992 that recognizes motor vehicle-related trauma as a major public health problem, and policy H-15.972 that encourages research and development of screening methods and articulates the physician's role in advising patients on driving safety (AMA, 2011b).

The AMA in cooperation with NHTSA developed a guide to assist physicians in assessing and counseling older drivers, providing information on patients at increased risk for unsafe driving, approaches to assessing functional abilities, the role of the physician, state reporting laws and description of medical conditions that may impair driving (AMA, 2010). These conditions grouped into Vision and Hearing loss, Cardiovascular diseases, Neurologic diseases, Cerebro-vascular diseases, Metabolic disorders, Musco-skeletal disabilities, Peripheral vascular disorders, Renal disease and Respiratory diseases (AMA, 2010).

As with state licensing requirements, mandated physician reporting is controversial. Some argue that mandatory reporting regulation may force physicians into defensive reporting and are based on unproved screening tools that may damage physician-patient relationships (K. Snyder & Bloom, 2004). The concern on physician's reliance on unproven tools and tests for referring patient to DMV for further testing has been documented. For example, studies examining whether physicians were able to distinguish older drivers with suspended licenses from matched controls by using simple medical examination showed that a simple medical exam was insufficient to distinguish the license status of the patients (Johansson et al., 1996). However, when physician made use of the patient's medical history, medication use, drawing and memory tests, MMSE scores as well as visual acuity tests, they were able to significantly distinguish patients with suspended licenses from controls. Furthermore, older adults with suspended licenses were significantly more likely to be suspected of mild dementia than controls (Johansson, et al., 1996).

Some have argued that mandated physician reporting may also lead patients to hide potentially dangerous conditions from their physicians for fear of losing licenses (Aschkenasy, Drescher, & Ratzan, 2006b; K. Snyder & Bloom, 2004) and others have strongly argued that physicians are not adequately trained in detecting driving-related conditions (Aschkenasy, et al., 2006b). Those in favor of mandated physician reporting call for "negligent failure to report" regulations to hold physicians responsible for failing to appropriately assess their patient's fitness to drive (K. Snyder & Bloom, 2004). This may lead some physicians to face uncertainties on their role and obligations.

A study of the Canadian law mandating cardiac illness reporting found that such mandatory physician reporting had a negligible impact on crashes with only one death or serious injury being attributed to this reporting (Simpson et al., 2000a). Similarly a study of the Canadian law requiring physicians to report patients with epilepsy found no support for claims of decreases in crash involvement following the introduction of the law (McLachlan, Starreveld, & Lee, 2007).

1.3.7 Enforcement of screening and reporting laws

While physician members may adhere to AMA policies, physicians are required to obey their state's reporting requirements. For example, physicians practicing in Pennsylvania are required to report to the Pennsylvania Department of Motor Vehicles (DMV) any patient who has been diagnosed as having a condition that could impair their ability to safely operate a motor vehicle (PADOT, 2010a). In 2008, the Pennsylvania DMV received 27,000 reports by physicians about patients with medical impairments, of which 22% had their licenses revoked and 21% faced additional driving restrictions. Half of the reports were regarding older drivers (AMA, 2010). Furthermore physicians not reporting patients considered medically unqualified to operate a motor vehicle may be held responsible as cause of a crash resulting in death, injury or property loss caused by their patient (PADOT, 2010a, 2010b). Therefore, mandated physician reporting could be considered a significant factor in the restriction of driving for some older drivers, a factor that strongly merits scientific investigation.

Another state with mandated physician reporting is Oregon. A study by Snyder et al. (2009) reported that the introduction of mandated physician reporting resulted in loss of driving privileges for a small number of licensed drivers, of whom the majority were older than 80 with chronic or progressive cognitive impairments (K. M. Snyder & Ganzini, 2009). While the study did not examine the effect of mandated physician reporting on crashes, as with physician reporting in Pennsylvania, it showed that mandated physician reporting does result in the withdrawal of driving privileges of at-risk drivers.

2.0 METHODS

This study uses two main sources of data information to examine the role of licensing requirements and physician reporting laws on older driver safety. To examine the role of these laws on older driver fatal crashes, the Fatality Analysis Reporting System (FARS) was used. FARS is a census of motor vehicle crashes on public roadways that involved the death of a person within 30 days of the crash and it is maintained by the United States Department of Transportation (NHTSA, 2011). To examine the role of these laws on vehicle crash-related hospital admissions among older drivers, hospital admission data from US Hospitals, from 2004 to 2009 was used. This information is made available through the State Inpatient Databases (SIDs) of the Agency for Healthcare Quality and Research (AHRQ) Healthcare Cost and Utilization Project (HCUP), a public-private partnership. Details on how the SID data are collected can be found on the AHRQ website (Agency for Healthcare Research and Quality, 2008). The SID data is also used to examine the role of licensing and physician reporting laws on the prevalence of dementia among hospitalized drivers.

2.1.1 Identification of drivers, predictors and covariates

To identify fatally injured older adult drivers, retrospective cross-section data on fatal crashes was obtained from the 2004-2009 Fatality Analysis Reporting System (FARS). Records were selected if an older adult driver ages 55 or older was involved in a fatal crash, where the older adult driver was the fatal victim. Fatal crashes among drivers ages 55 to 59 were selected for study inclusion as a control variable to adjust for the influence of otherwise non-accounted factors in fatal crash rate differences between states. Over the 6 years of data available for the study, matched to states with comparable hospitalized driver information, a total of 32,370 drivers 55 and older were identified who were fatally injured as drivers in traffic.

To identify older adult drivers hospitalized due to motor-vehicle crashes, the SIDs were used. The SIDs contains patient information from standardized discharge abstracts that include demographic and clinical data at the patient level and information at the hospital level. Over the 6 years of data available for the study, a total of 136,987 drivers 55 and older, hospitalized due to motor-vehicle crash, were identified. In line with other hospital based studies, to avoid double counting, hospitalized adults were dropped if their incoming source was another hospital or long-term care center. Hospitalized drivers were identified based on discharge abstract ICD-9-CM External Causes of Injury Codes (E-codes) E810-E819 with a fourth digit of .0 (driver) in any of the first four E-code fields. Among these 136,987 hospitalized older drivers, 5,911 drivers with a diagnosis of dementia were also identified. Dementia was identified based on ICD-9-CM codes (294.8, .9, 298.9, 046,.0 -.3, 094, .1, 290.0, .1, .10 -.13, .20, .2-.4, .40 - .43, .8, .9, 2902.1, 437.0, 291, .1, .2, 292.82, 294.0, 294, 294.1, 345.0, 310, 310.1, 310.8-.9, 331,.0,- .9, .82, .89, 332,.0, 333.4, 437, .0, 797) in any of the first 10 patient diagnosis fields.

Since state hospitalization data sharing is voluntary, not all state hospitalization data were available for the whole period covered. There were 37 states reporting in 2004 and 2005, 39 in 2006, 40 in 2007, 32 in 2008 and 44 in 2009, resulting in 229 state-year observations or 916 state-quarter observations. The population of interest is drivers ages 60 and older and hospitalized drivers ages 55 - 59 were used as a comparison group to adjust for the influence of non-accounted factors in hospitalization rates between states.

Information on the state requirements on physician reporting of at-risk drivers and legal protection of reporting physicians was obtained from Physician's Guide to Assessing and Counseling Older Drivers, 1st and 2nd editions, published in 2004 and 2010 by the American Medical Association (AMA) and the National Highway Traffic Safety Administration (NHTSA), state DMV's, the AAA Foundation's License Policy and Practices Database (AAA, 2011). Data on older driver state licensing requirements were obtained from the AAA Foundation's License Policy and Practices Database (AAA, 2011), the Insurance Institute for Highway Safety (IIHS) older drivers, licensing renewal provisions (IIHS, 2011b), state DMV's, and the AMA/NHTSA Physician's Guide to Assessing and Counseling Older Drivers, 1st and 2nd editions (AMA, 2004, 2010).

Data for annual State and age-group specific data on driver licensing was obtained from the US Federal Highway Administration's (FHWA) annual Highway Statistics publications (FHWA, 2004-2009). Data on adjusting variables were collected from a number of sources. Seatbelt requirements were obtained from the IIHS belt-use laws depository (IIHS, 2011d). Urban and rural speed limits were also obtained from the IIHS (IIHS, 2011c). Data on annual total state precipitation was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NOAA, 2011) whereas data on annual state motor-fuel consumption was obtained from the US Federal Highway Administration's annual Highway Statistics publications 2004-2009 (FHWA, 2004-2009).

Data on trauma center access reflects access to Trauma I and II centers within 45 minutes as collected in 2005 by Branas and colleagues (Branas et al., 2005). Data on annual state unemployment rates were obtained from the US Department of Labor's Bureau of Labor Statistics (BLS)(BLS, 2011). The University of Pittsburgh institutional review board categorizes this study as exempt. All analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, North Carolina).

Since mandated physician reporting of a broad category of at-risk drivers may substantially influence the driving population of a state and subsequently the crash-related hospitalizations of drivers in that state, a variable indicating this state characteristic was created. A binary variable denoting whether a state requires physician reporting was created, with 3 states mandating physician reporting of at-risk drivers that go beyond those with conditions such as Epilepsy or those characterized by loss of consciousness. Therefore only states with broad definitions of at-risk drivers that mandated physician reporting were categorized as such. A second binary variable was created to denote whether a state provided legal protection, such as immunity, to reporting physician, regardless if reporting was required by law. Among HCUP participating states, 23 states provided such protection.

Variables indicating State licensing requirements thought to influence driver safety were also generated for each age group to best reflect the licensing requirements for that age cohort. One such requirement is that drivers present in-person for license renewal at least once within two or three renewal cycles, rather than using other renewal modes such as mail, phone or the web. This is thought to allow DMV personnel to assess driver's driving fitness. A binary variable indicating whether such requirement was in place was generated. Only 5 states did not require in-person renewals.

Other licensing requirements applied include road test at licensing renewal and vision testing. From participating states, only two states required a road test for license renewal.

Among analyzed states, 36 states required vision acuity testing when presenting in-person for license renewal, as a precondition to continued driving. As these requirements changed across states at varying ages, vision testing variables were established for each age-group. Furthermore, state license renewal periods, measured in years, was also included in model. Renewal period indicating the license validity length, varied considerably among those 60 to 70, with less variability among the older age groups.

In addition to State physician reporting requirements and licensing requirements, 8 other variables related to older driver safety were generated to be included as adjusting variables. The state's seat-belt enforcement requirements were reflected in a binary variable indicating whether a State practices primary seat-belt enforcement, whereby being unbelted is sufficient reason for police enforcement. Another element that may influence the likelihood of crash-related hospitalization is state's weather conditions. States annual total precipitation was used to represent this element in the model. A continuous variable reflecting precipitation was computed. Adverse weather conditions, especially rain, are considered road hazards for many drivers, and older drivers are known to avoid driving during inclement weather, hence the need to adjust for this factor given its variation across the United States (Kostyniuk & Molnar, 2008; Okonkwo, Crowe, Wadley, & Ball, 2008). A binary variable reflecting the speed limits in State's urban areas was included as well, indicating whether the speed limit in urban roads was equal or higher than 60 mph.

When quarterly frequencies of driver fatal crashes and driver hospitalizations were extracted from the databases (FARS and SID), a variable indicating patient's gender was also extracted. Similarly, an indicator variable for patient's rural or urban location was extracted, and included in the analyses as a control variable. Since the comparisons are made at the state-quarter level, that helps adjust for any differences for both hospitalizations and fatal crashes between states that may follow a seasonal trend. Similarly we also created a variable to indicate states region, as to control for any region-wide characteristics in hospitalizations and fatal crashes. States were separated into four regions (West, Midwest, Northeast and South) based on US Census Bureau Regional divisions (Census, 2009).

To adjust for differences in emergency care access between states among older adults involved in crashes, a variable denoting access to trauma centers was included. This variable indicates the proportion of the state's population that have access to Trauma I and II centers within 45 minutes of their residence as collected in 2005 (Branas, et al., 2005). Furthermore, to adjust for any state differences in road infrastructure, safety features of on-road vehicle fleet and other factors (Evans, 1991; Ruhm, 1996), a variable indicating annual real state GSP per capita income was included. To further adjust for any differences in driving exposure, a variable indicating states annual fuel consumption per capita was entered in the model (FHWA, 2004-2009).

2.1.2 Analyses

To address the role of licensing and medical reporting requirements on older driver safety three outcome measures are used. The first outcome measure is the number of fatal motor-vehicle crashes for older adults per state according to the specified age-group, observed at each quarter. The second outcome measure is the number of hospitalized older adults per state according to the specified age-group, observed at each quarter. The third outcome measure is the number of hospitalized drives with a diagnosis of dementia out of all hospitalized drivers, per specified age-group, measured annually. The third outcome uses annual measures as the lower counts at the quarter lever would have forced approach changes due to a high number of zeros.

2.1.3 State-level count models

The analyses for the first and second outcomes rely on count modeling. The first outcome uses counts or numbers of fatally crashed older drivers as each state-quarter over a 6 year period. This approach estimates the effect of specified licensing and medical reporting requirements on the number of fatal crashes among older adults adjusted for the number of licensed adults in that state-year for each of the specified age-cohorts. Similarly, the second outcome estimates the effect of specified licensing and medical reporting requirements on the number of hospitalized older adults, adjusted for the number of licensed adults in the state.

Because of the characteristics of our data, namely state-quarter level counts and a data-set with higher variability than expected in a Poisson distribution based model, Negative binomial regression was deemed as the most appropriate count information modeling approach. The presented models showed significant over-dispersion for all age-cohort analyses, indicating over-dispersion of the response variable, and indicating lack of fit for a potential Poisson distribution model.

The negative binomial regression model is a good way of modeling heterogeneity in populations due to differences in distributions as it accounts for over-dispersion of data (Hilbe, 2008). GEE based empirical standard error estimates were used to obtain confidence intervals based on an autoregressive first order correlation structure at the state level. To further adjust computed confidence intervals, the dscale option in proc genmod was used to correct the correlation matrix based confidence intervals for any data over-dispersion. In most instances this correction made little difference in the confidence interval, as model deviance was very close to a 1 (Pedan, 2001; UCLA, 2011). Using negative binomial models with generalized estimating equations allows for estimation of population-averaged coefficients, which indicate the effect of selected predictors on the whole population, rather than a particular individual in the samples (Hilbe, 2008). Studies show that compared to random effects models using maximum likelihood method procedures; negative binomial achieves similar results (Allison, 2005; Hu, Goldberg, Hedeker, Flay, & Pentz, 1998)

For each age-group model, fit was determined using deviance and scaled deviance from each model. In all analyses deviance and scaled deviance values approximated a chi-square distribution and resulting value (when dividing with degrees of freedom) remained close to 1, indicating a good fit and yielding accurate standard errors for chi-square statistics. Following this determination, the GEE analyses, were requested for each of the age-cohort specific models. At this stage, the quasi-likelihood independent criterion (QIC) was used to inform the best model specification (SAS, 2011). The QIC is based on the Akaike's information criterion (AIC) widely used on other forms of regression, that cannot be directly applied to GEE based estimates due to GEE's non-likelihood based approach (Pan, 2001). Based on this criterion, two non-significant parameters that decreased model fit, namely GDP per state capita and rural urban speed, were removed from the model. It is assumed that the final models specified adequately controlled for these two conditions by maintaining a patient's urban/rural location and the state's unemployment rates.

2.1.4 Person-level logistic models

The person-level model uses logistic regression to examine the role of licensing and physician reporting requirements on the prevalence of dementia among hospitalized older drivers. The total number of hospitalized drivers per age group is used as the denominator on which the probability of hospitalized drivers having a diagnosis of dementia is based. In addition to gender, patient urban or rural location, diagnosis of dementia, race was considered as an additional person-level control variable, however due to the large number of missing values (>25%), this variable was dropped from consideration.

In addition to examining the role of identified predictors on hospitalization rates of adult drivers, separate models were specified examining their role on the number of drivers with a diagnosis of dementia among hospitalized drivers. The role of mandated physician reporting requirements is of special interest in this examination, given the hypothesis that states that mandate physician reporting are expected to have a healthier driving population and thus a lower representation of drivers with dementia, as a proxy measure, among the crash-related hospitalized drivers. The Hosmer and Lameshow goodness of fit test is used to assess accurate specification (Hosmer, 2000). All models computed use Generalizes Estimating Equations (GEE), an adjustment method developed by Liang and Zeger (1986) and used by SAS, to apply generalized linear models (GLM) to our data, treated as repeated measures data (Zeger & Liang, 1986) . The Huber-White adjusted standard errors for confidence interval are also used for estimates and presented for each age-specific model. In order to account for the non-independence of observations, GEE applies an additional term, indicating correlation between observations at the cluster specified, to the model. In our case this term is computed using an autoregressive correlation structure, a structure which in our case argues that hospitalizations that occur closer in time have a higher correlation than those with larger time intervals. While GEE based estimates are robust to potential correlation structure misspecification, the auto-regressive structure of correlation of within-cluster observations is most appropriate for our data as they contain a time order component (Hosmer, 2000; Pan, 2001) This approach produces the most conservative standard error estimates and is appropriate given the changing driving environment.

2.1.5 Adjustments

All models computed use Generalizes Estimating Equations (GEE), an adjustment method developed by Liang and Zeger (1986) and used by SAS, to apply generalized linear models (GLM) to our data, treated as repeated measures data (Zeger & Liang, 1986) . In order to account for the non-independence of observations, GEE applies an additional term, indicating correlation between observations at the cluster specified, to the model. In our case this term is computed using an autoregressive correlation structure, a structure which in our case argues that hospitalizations that occur closer in time have a higher correlation than those with larger time intervals. While GEE based estimates are robust to potential correlation structure misspecification, the auto-regressive structure of correlation of within-cluster observations is most appropriate for our data as they contain a time order component (Hosmer, 2000; Pan, 2001) This approach produces the most conservative standard error estimates and is appropriate given the changing driving environment. In addition to adjusting for the lack of independence between observations at the state-quarter level, this approach also adjust for any seasonality effects on driver hospitalizations, as the time of observation is the annual quarters.

As Zeger, Liang and Albert (1988) note the main feature that distinguishes person-level models from our count-based model is that the regression coefficient presented describes the average population response to changes in specified independent variables (Zeger, et al., 1988).

We further apply a finite sample correction to standard errors. This is done to account for the finite cluster possibilities in our sample, finite number of states that serve as clusters. Furthermore, as our sample accounts for more than 5% of total population, a finite correction is warranted (Cohen, Cohen, West, & Aiken, 2002).

3.0 ROLE OF DRIVER LICENSING AND PHYSICIAN REPORTING LAWS ON OLDER DRIVER FATAL CRASHES

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3.1 ABSTRACT

Objective: To determine the effect of state licensing and physician reporting requirements on older driver fatal crashes, guided by the hypothesis that states with stricter licensing requirements and mandatory physician reporting would yield lower fatal crash rates.

Methods: Fatal crashes from the US Fatality Analysis Reporting System (FARS) for drivers 60 and older were selected (n=24,399; 70% male). Fatal crash incidence rates were estimated using three count models (negative binomial) to examine the effect of state licensing requirements, including in-person renewal, vision testing, road testing and length of renewal cycle, and risky driver physician reporting laws that include mandated physician reporting and legally protected reporting laws. Models adjusted for person-level covariates that include driver gender, urban/rural crash location and state-level covariates that include number of licensed drivers, state primary seat-belt enforcement laws, state unemployment rate, annual state total precipitation, state per capita fuel consumption, access to trauma centers and urban speed limits.

Results: Vision testing when renewing in person showed consistent association with lower fatal crash rates among four of the six age groups examined. Vision testing was especially predictive of a lower crash fatality rate among drivers ages 80 to 84 resulting in an (incident rate ratio [IRR], 0.81; 95% confidence interval [CI] 0.69; 0.96) when adjusting for covariates, regional differences and driver ages 55 to 59 fatal crash rates. In-person renewal had borderline association with a lower crash rate among drivers 80 to 84. Surprisingly, road testing was associated with an elevated fatal crash rate in states with such a requirement for drivers 85 and older [IRR 1.43 (95% CI 1.2; 1.71)]. There was no significant association between state mandated physician reporting requirements, legally protected physician reporting requirements with fatal crash rates among groups examined.

Conclusions: Vision testing at in-person renewal was related to significantly lower fatal crash rates among four of the six age groups examined. Other state licensing laws such as in-person renewal and road testing indicated borderline association with fatal crash rates among select groups. Physician reporting laws, mandated or legally protected, and length of licensing renewal lacked any independent association with fatal crash rates.

3.2 INTRODUCTION

In 2009, some 175,000 adults 65 and older were admitted to emergency departments due to crash related injuries, with another 31,000 further transferred or hospitalized (CDC, 2011). In that same year 4,396 adults 65 and older were killed as drivers of a motor vehicle in-transport (NHTSA, 2011). Since 2001 some 1.4 million older adults have received emergency department (ED) treatment (CDC, 2010) and over 64,000 have died due to motor vehicle (MV) injuries (NHTSA, 2009) and motor-vehicle related hospitalizations and injuries for 2008 alone have resulted in an estimated $3 Billion in direct medical cost (Corso, et al., 2006; Naumann, et al., 2010)

Some argue that after teenage males, older adults have the highest per capita MV fatality rate (Morrisey & Grabowski, 2005; NHTSA, 1999) making it the second leading cause of injury death after falls (CDC, 2010). Other show that MV-related injuries result in significant post-crash disability, accounting for 25% of limitations in activities of daily living (ADL) among those with injury-related chronic disabilities (Guerrero JL, 1999). And by 2050 there will be some 88.5 million older adults, representing 25% of the driving population, an increase from the current 16.1% of the driving population (US Census, 2009). Following current trends it is expected that more than 80% of older adults will be licensed to drive.

Additionally while studies show that age-related declines in vision and cognitive functioning as well as physical changes, may affect some older adults' driving performance (Owsley, 1999), age is only mildly correlated with driving performance in models that adjust for co-morbid conditions (Grabowski, et al., 2004a). Others have demonstrated that only older drivers that drive fewer than 1900 annual miles (3000 km) are at increased risk of crash

(Langford, et al., 2006) or have shown that increased fatality rates among older drivers may be due their inherent fragility (Li, et al., 2003).

Nevertheless, state governments, to the dismay of many older drivers, have introduced different requirements for ensuring the safety of the driving public, including that of the older driver. A number of states now mandate physician reporting of patients with driving-related medical conditions and have introduced stringent age-based licensing screening criteria that require in-person renewals, vision tests, physician reports, written and road tests as well as a shorter license renewal period. The purpose of this study is to examine the role of state driver licensing laws and physician reporting requirements on older driver fatal crashes. Findings will contribute to the safety and wellbeing of older adults by determining appropriate licensure policies and the optimal role of physicians in older driver safety.

3.3 METHODS

3.3.1 Study population

Retrospective cross-section data on fatal crashes was obtained from the 2004-2009 Fatality Analysis Reporting System (FARS), a census of motor vehicle crashes on public roadways that involved the death of a person within 30 days of the crash. Cases were defined as older adult drivers 55 and older involved in a fatal crash, where the older adult driver was the fatal victim. Fatal crashes among drivers ages 55 to 59 were also selected for study inclusion as a control variable to adjust for the influence of otherwise non-accounted factors in fatal crash rate differences between states.

A total of 24,399 drivers 60 and older in fatal crashes were identified, with another 7,971 drivers 55 to 59 included for comparison purposes. Of the total 24,399 fatal crash drivers ages 60 and older identified, 17,080 were male drivers (70%) and drivers ages 60-64 made up the largest proportion of crashed drivers (24.5%) with drivers over the age of 85 accounting for the smallest proportion of fatal deaths (11.4%).

3.3.2 Study variables

Information on the state requirements for mandatory physician reporting of at-risk drivers and legal protection of reporting physicians was obtained from Physician's Guide to Assessing and Counseling Older Drivers, 1st and 2nd editions, published in 2004 and 2010 by the American Medical Association (AMA) and the National Highway Traffic Safety Administration (NHTSA). Information of laws was also obtained from state department of motor vehicles (DMV) and the AAA Foundation's License Policy and Practices Database (AAA, 2011). Data on older driver state licensing requirements were obtained from the AAA Foundation's License Policy and Practices Database (AAA, 2011), the Insurance Institute for Highway Safety (IIHS) older drivers, licensing renewal provisions (IIHS, 2011b), state DMV's, and the AMA/NHTSA guides (AMA, 2004, 2010).

Data for annual state and age specific data on driver licensing was obtained from the US Federal Highway Administration's (FHWA) annual Highway Statistics publications (FHWA, 2004-2009), whereas data on state's age specific population was obtained from the US Census Bureau (Census, 2011). These data served as denominator counts for analyses conducted. Data on average annual vehicle miles traveled for 2009 was obtained from the 2009 National Household Transportation Survey (FHWA, 2011)

Data on adjusting variables were collected from a number of sources. Seatbelt requirements were obtained from the IIHS belt-use laws depository (IIHS, 2011d). Urban and rural speed limits were also obtained from the IIHS (IIHS, 2011c). Data on annual total state precipitation was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NOAA, 2011) whereas data on annual state motor-fuel consumption was obtained from the US Federal Highway Administration's annual Highway Statistics publications 2004-2009 (FHWA, 2004-2009).

Data on trauma center access reflects access to Trauma I and II centers within 45 minutes as collected in 2005 by Branas and colleagues (Branas et al., 2005). Data on annual state unemployment rates were obtained from the US Department of Labor's Bureau of Labor Statistics (BLS)(BLS, 2011). The University of Pittsburgh institutional review board classifies this study as exempt. All analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, North Carolina).

3.3.3 Parameterization of variables

Quarterly counts of motor-vehicle fatal crashes by state and age groups were extracted from the Fatality Analysis Reporting System, with drivers grouped into 7 age cohorts (55-59, 60-64, 65-69, 70-74, 75-79, and 80-85, 85 and older) to achieve a more accurate representation of the various driving requirements. Since mandated physician reporting of a broad category of at-risk drivers may substantially influence the driving population of a state and subsequently driver crashes in that state, a variable indicating this state characteristic was created. A binary variable denoting whether a state requires physician reporting was created, with three states mandating physician reporting of at-risk drivers that go beyond narrow definitions such as Epilepsy or those characterized by loss of consciousness. Hence only states with broad definitions of at-risk drivers that mandated physician reporting were categorized as such. A second binary variable was created to denote whether a state provided legal protection, such as immunity, to reporting physician, regardless if reporting was required by law.

Variables indicating state licensing requirements thought to influence driver safety were also generated for each age group to best reflect the licensing requirements for that age cohort. Such requirement include that drivers present in-person for license renewal at least once within two or three renewal cycles, rather than using other renewal modes such as mail, phone or the web. This is thought to allow DMV personnel to assess driver's driving fitness. A binary variable indicating whether such requirement was in place was generated. Among selected states, only 5 states did not require in-person renewals. Other licensing requirements applied include road test at licensing renewal and vision testing. From participating states, only two states required a road test for license renewal. Among analyzed States, 36 states required vision acuity testing as a precondition to continued driving, when presenting in-person for license renewal. Furthermore, state license renewal periods, measured in years, was also included in model. Renewal period indicating the license validity length, varied considerably among those 60 to 70, with less variability among the older age groups.

In addition to state physician reporting requirements and licensing requirements, 8 other variables related to older driver safety were generated to be included as adjusting variables. The state's seat-belt enforcement requirements were reflected in a binary variable indicating whether a state practices primary seat-belt enforcement, whereby being unbelted is sufficient reason for police enforcement. Another element that may influence the likelihood of crash-related hospitalization is state's weather conditions. States annual total precipitation was used to represent this element in the model. A continuous variable reflecting precipitation was computed. Adverse weather conditions, especially rain, are considered road hazards for many drivers, and older drivers are known to avoid driving during inclement weather, hence the need to adjust for this factor given its variation across the United States (Kostyniuk & Molnar, 2008; Okonkwo, Crowe, Wadley, & Ball, 2008). A binary variable reflecting the speed limits in state's urban areas was included as well, indicating if speed limit in urban roads was equal or higher than 60 mph.

Person-level covariates extracted from the database include patient's gender and urban/rural crash location. These covariates were included in all analyses. State-quarter comparisons help adjust for any differences for crash trends due to a seasonal trend. Similarly an indicator of region was created to adjust for any region-wide characteristics in crashes. States were separated into four regions (West, Midwest, Northeast and South) based on US Census Bureau Regional divisions (Census, 2009). To adjust for any differences in emergency care access, and resulting probability in being included in the FARS database, a variable denoting access to trauma centers was included. This variable indicates the proportion of the state's population that have access to Trauma I and II centers within 45 minutes of their residence as collected in 2005 (Branas, et al., 2005). And to adjust for any state differences in road infrastructure, safety features of on-road vehicle fleet and other factors (Evans, 1991; Ruhm, 1996), a variable indicating annual real state GSP per capita income was included, whereas a variable indicating states annual fuel consumption per capita was selected to adjust for any differences in driving exposure (FHWA, 2004-2009).

A natural log transformed variable for each age-cohort denoting the number of licensed drivers per state and year was computed to serve as a measure of exposure, offset variable, for analyses. In SAS, exposure measure is log transformed prior to inclusion as an offset variable (Pedan, 2001; UCLA, 2011). For fatally crashed drivers, it is the annual age-cohort specific total licensed driver counts that serve as the measure of exposure.

3.3.4 Statistical analyses

Differences in motor vehicle fatal crashes incidence rates among older adult drivers in states with varying driver licensing requirements were examined using three separate generalized estimating equations (GEE) negative binomial regression models, detailed below. Because of the characteristics of our data, namely state-quarter level fatal crash counts and a data-set with higher variability than expected in a Poisson distribution based model, negative binomial regression was deemed as the most appropriate count information modeling approach. The presented models showed significant over-dispersion for all age-cohort analyses, indicating over-dispersion of the response variable resulting in a lack of fit for a potential Poisson distribution model. The negative binomial regression model is a good way of modeling heterogeneity in populations due to differences in distributions as it accounts for over-dispersion of data (Hilbe, 2008). GEE based empirical standard error estimates were used to obtain confidence intervals based on an autoregressive first order correlation structure at the state level. To further adjust computed confidence intervals, the dscale option in proc genmod was used to correct the correlation matrix based confidence intervals for any data over-dispersion. In most instances this correction made little difference in the confidence interval, as model deviance was very close to 1 (Pedan, 2001; UCLA, 2011). Using negative binomial models with generalized estimating equations allows for estimation of population-averaged coefficients, which indicate the effect of selected predictors on the whole population, rather than a particular individual in the samples

(Hilbe, 2008). Studies show that compared to random effects models using maximum likelihood method procedures; negative binomial achieves similar results (Allison, 2005; Hu, Goldberg, Hedeker, Flay, & Pentz, 1998)

For each age-group model, fit was determined using deviance and scaled deviance from each model. In all analyses deviance and scaled deviance values approximated a chi-square distribution and resulting value (when dividing by degrees of freedom) remained close to 1, indicating a good fit and yielding accurate standard errors for chi-square statistics. Following this determination, the GEE analyses, were requested for each of the age-cohort specific models. At this stage, the quasi-likelihood independent criterion (QIC) was used to inform the best model specification (SAS, 2011). The QIC is based on the Akaike's information criterion (AIC) widely used on other forms of regression, that cannot be directly applied to GEE based estimates due to GEE's non-likelihood based approach (Pan, 2001). Based on this criterion, two non-significant parameters that decreased model fit, namely GDP per state capita and rural urban speed, were removed from the model. It is assumed that the final models specified adequately controlled for these two conditions by maintaining a patient's urban/rural location and the state's unemployment rates.

3.3.5 Model specifications

Model 1 (M1): The first model specification examines the number of fatally crashed drivers for each of the 7 age cohorts, as previously defined, using multivariate negative binomial regression. The outcome measure is the number of fatally crashed drivers per age-group specified, with the set of independent variables including mandatory physician reporting, legally protected reporting, at least one in-person renewal within 3 renewal cycles, states' in-person only renewal requirements and renewal period. A number of adjusting variables were also included, such as patient's gender, patient's urban or rural location, state's primary seat-belt enforcement requirements, annual precipitation, fuel consumption, unemployment rate, proportion of state's population with 45 minute access to trauma 1 and 2 centers and variable indicating state's urban speed limit over 60 mph. Road testing was only included for models with ages 75 and older. **Model 2 (M2):** The second model specification includes the set of variables from the previous models, with the additional inclusion of a design variable for region, to adjust for regional differences. **Model 3 (M3):** The third model specifications is one that in addition to the set of variables included in model 2, includes the linear parameter to indicate the fatal crash counts of drivers ages 55 to 59 in the model. This approach, also called Differences-in-Differences (DD) estimation, treats fatal crashes of drivers 60 and older as cases that are under the influence of the state laws and regulations examined in this study and the fatal crashes of drivers under 60 years old as controls, as drivers that are not directly influenced by the age-based licensing and medical reporting laws. By including the quarterly fatal crashes of those under 60, this approach allows for the estimation of the difference in effect of the state laws on the difference in hospitalization between the groups (Ruhm, 1996). This follows the assumption that the difference between the fatal crashes of the two groups within each state quarter will remain constant if age-based licensing and reporting requirements have no impact on the fatal crash trends of targeted older drivers. This approach also has the effect of using the population of fatally crashes drivers 55 to 59 as a way to adjust for the heterogeneity of the populations being compared and is in line with previous studies (Grabowski, et al., 2004a). A main assumption of this DD estimation approach is that there should be no other major factor that affects the difference in the fatal crash counts between those under 60 and older than 60 at the state-quarter level (Thomas S. Dee, 2001; Gruber, 1994).

3.4 RESULTS

3.4.1 Results

Among the 24,399 fatally crashed drivers 60 and older, 2,571 (10.5%) crashed in states mandating physician reporting of at risk drivers. Some 16,444 (67.4%) older drivers fatally crashed in states that permit physician reporting of at risk drivers and offer legal protection, such as immunity, to reporting physician.

Table 4: Characteristics of fatal crash drivers

		No.	%
Mandatory physician reporting			
	No	21,828	89.5
	Yes	2,571	10.5
Physician reporting (LP)			
	No	7,955	32.6
	Yes	16,444	67.4
In-person renewal			
	No	2,298	9.4
	Yes	22,101	90.6
Vision testing at renewal			
	No	3,445	14.1
	Yes	20,954	85.9
Road Testing			
	No	9,611	95.7
	Yes	430	4.3
Driver gender			
	Male	17,080	70.0
	Female	7,319	30.0

Table 4: Continued

Age Group			
	60-64	5,997	24.5
	65-69	4,508	18.5
	70-74	3,853	15.8
	75-79	3,880	15.9
	80-84	3,374	13.8
	85+	2,787	11.4

LP – Legally Protected

A requirement of in-person renewal was in-effect in the states where 22,101 (90.6%) of identified drivers fatally crashed and vision testing at renewal was in effect in states that reported 20,954 fatally crashed older drivers (85.9%). States that require road testing had 430 fatal older driver crashes, or 4.3% of all fatal crashes among those 75 and older.

Demographic results indicate that among identified older adults drivers in fatal crashes, 17,080 (70%) were male and drivers ages 60 to 64 and those 65 to 69 accounted for the largest proportion of fatally crashed drivers among those identified, 24.5% and 18.5% respectively (Table 4.)

Table 5 presents the pooled driver fatality rates based on 2004-2009 state population person-years and 2004-2009 state licensed population person-years. Based on the number of licensed drivers per age group, drivers 55-59 had 4.5 fatal crashes per 100,000 licensed person-years, and 4.26 fatal crashes per 100,000 person-years. This rate changed to 9.3 driver fatal crashes per 100,000 licensed person-years drivers among those 85 and older, or 5.18 driver fatal crashes per 100,000 person-years. Using both licensed drivers and population size as denominators, marked group differences are seen starting with 75-79 year olds.

Table 5: 2004-2009 Fatal Driver Crash Rates

Age Group	Fatal Driver Crashes	Person-years	Person-years (Licensed)	Driver Fatality Rate per 100,000 Person Years	Driver Fatality Rate per 100,000 Licensed Person Years
55-59	7,971	187,088,729	177,324,051	4.26	4.50
60-64	5,997	146,306,772	139,283,316	4.10	4.31
65-69	4,508	111,471,291	102,889,360	4.04	4.38
70-74	3,853	90,265,123	78,640,390	4.27	4.90
75-79	3,880	77,162,186	62,925,933	5.03	6.17
80-84	3,374	59,621,191	44,029,240	5.66	7.66
85+	2,787	53,798,693	29,956,387	5.18	9.30

Table 6 presents a similar rate examination using the number of vehicle miles traveled (VMT) as the measure of exposure. As average vehicle miles traveled (VMT) for examined age groups were only available for 2009 from the 2009 National Household Travel Survey, rates are estimated only for fatal crashes occurring in 2009. On a per 100 million VMT basis, drivers 55-59 have the lowest fatal crash involvement rate, increasing to 1 fatal crash per 100 million VMT for those 70-74 and to 3.38 for those over age 85, primarily given the lower annual miles traveled for this age group. As when using licensed drivers and population size, fatal crash involvement appears to increase markedly past age 75.

Table 6: 2009 Fatal Driver Crash Rates per VMT

Age Group	Fatal Driver Crashes	Licensed Drivers	Average VMT per group	Estimated VMT	Driver Fatality Rate per 100 Million Miles Traveled
55-59	1,348	17,265,661	12,794	220,909,988,736	0.61
60-64	1,126	14,511,411	11,427	165,831,906,371	0.68
65-69	814	10,606,519	10,140	107,550,314,790	0.76
70-74	641	7,677,953	7,964	61,149,751,416	1.05
75-79	580	5,846,475	6,951	40,644,635,735	1.43
80-84	572	4,222,747	5,335	22,532,451,310	2.54
85+	455	3,135,103	4,299	13,477,807,797	3.38

3.4.2 Model results

Across all model specifications there was no association between state mandated physician reporting requirements and state fatal crash rates, represented in Incident Rate Ratios (IRR). Similarly, legally protected physician reporting also showed no association with state's crash rate across the majority of age-groups, with the potential exception for drivers 85 and older, in the 1st model specifications that does not account for regional differences or crash trends among drivers ages 55 to 59. This association was only significant at the 0.10 alpha level with an IRR 1.13 (95% Confidence Interval (CI), 0.98; 1.32). State requirements for in-person renewals showed significant association only among drivers 80-84 across all model specifications, including M2 and M3, which adjust for regional differences as well as crash trends among those 55 to 59. This state licensing provision was associated with a IRR of 0.87 (95% CI 0.75; 1.00) at the 0.10 level (M1), and an incidence rate ratio of 0.82 (95% CI 0.68; 0.98) at an 0.05 alpha level when adjusting for state differences (M2) and IRR 0.84 (95% CI 0.70; 1.01) when also including the linear fatal crashes rate parameter of those 55 to 59. For drivers 60 to 64 the 2nd specification adjusting for regional differences indicated a lower incidence rate for states with in-person renewal requirements with IRR 0.86 (95% CI 0.75; 0.98), and for those 65-59 the resulting rate ratio was IRR 0.87 (0.76; 1.00) and IRR 0.83 (95% CI 0.70; 0.98) those 70 to 74.

Vision testing when renewing in-person showed the most consistent association with fatal crash rates among the predictors tested. At least one model showed vision testing was significantly associated with outcome in 4 of the 6 age groups, and for drivers 80-84, model 1, 2 and 3 indicated a lower crash incidence IRR 0.82 (95% CI 0.70; 0.96), IRR 0.79 (95% CI 0.67; 0.93) and IRR 0.81 (95% CI 0.68; 0.96), respectively.

Road testing was only included in models for drives ages 75 and older, as this requirement does not apply to other age groups. For all three age groups (75-79, 80-84 and 85 and older) the regression coefficient and resulting IRR seem to indicate an increase in crash rates in states with mandated road testing. While this requirement was significant in one of three model specifications for those 75 to 79, and two of three models for drivers 80 to 84, all models indicated significant association among drivers 85 and older. For those 85 and older, the incidence rate ranged from IRR 1.53 (95% CI 1.18; 1.98) to 1.43 (95% CI 1.20; 1.71) when adjusting for crash trends of those 55 to 59. A longer renewal license renewal also showed significant association with crash incidence rates for those 80 to 84 with an IRR of 0.96 (95% CI 0.91; 1.00).

Table 7: Negative binomial models - Fatal crashes according to state laws

		Mandatory physician reporting	Physician reporting (Protected)	In-person renewal	Vision testing when in-person	Road test	Renewal period
60-64	States without Law	5,319	1,968	525	830		NA
	States with Law	678	4,029	5,472	5,167		
	Adjusted Incident RR (95% CI) M1	1.01 (0.82; 1.25)	1.02 (0.85; 1.23)	1.01 (0.86; 1.19)	0.88 (0.75; 1.03)	NA	1.00 (0.97; 1.03)
	Adjusted Incident RR (95% CI) M2	1.01 (0.79; 1.28)	0.98 (0.84; 1.15)	0.96 (0.78; 1.18)	0.86 (0.75; 0.98)*		1.00 (0.97; 1.03)
	Adjusted Incident RR (95% CI) M3	0.99 (0.8; 1.23)	0.98 (0.85; 1.13)	1.00 (0.84; 1.18)	0.90 (0.78; 1.03)		0.99 (0.97; 1.02)
65-69	States without Law	4,020	1,458	413	642		NA
	States with Law	488	3,050	4,095	3,866		
	Adjusted Incident RR (95% CI) M1	1.05 (0.89; 1.24)	1.03 (0.83; 1.28)	0.93 (0.81; 1.06)	0.87 (0.75; 1.02)	NA	1.02 (0.98; 1.05)
	Adjusted Incident RR (95% CI) M2	1.02 (0.83; 1.24)	0.99 (0.82; 1.2)	0.88 (0.72; 1.08)	0.87 (0.76; 1.00)**		1.00 (0.96; 1.04)
	Adjusted Incident RR (95% CI) M3	1.01 (0.83; 1.22)	0.98 (0.83; 1.16)	0.92 (0.78; 1.09)	0.90 (0.79; 1.03)		1.00 (0.96; 1.04)
70-74	States without Law	3,475	1,234	352	564		NA
	States with Law	378	2,619	3,501	3,289		
	Adjusted Incident RR (95% CI)	1.04 (0.81; 1.33)	1.08 (0.86; 1.36)	0.94 (0.81; 1.09)	0.85 (0.69; 1.05)	NA	1.00 (0.96; 1.05)
	Adjusted Incident RR (95% CI) M2	1.07 (0.82; 1.42)	1.03 (0.85; 1.25)	0.87 (0.72; 1.04)	0.83 (0.70; 0.98)*		0.97 (0.92; 1.02)
	Adjusted Incident RR (95% CI) M3	1.07 (0.80; 1.41)	1.02 (0.85; 1.22)	0.9 (0.75; 1.07)	0.86 (0.71; 1.03)		0.97 (0.92; 1.03)

Table 7: Continued

75-79	States without Law	3,497	1,284	394	554	3,722	NA
	States with Law	383	2,595	3,486	3,326	158	
	Adjusted Incident RR (95% CI) M1	1.06 (0.82; 1.38)	1.02 (0.84; 1.23)	0.86 (0.7; 1.06)	0.89 (0.73; 1.08)	1.21 (0.89; 1.63)	1.02 (0.98; 1.06)
	Adjusted Incident RR (95% CI) M2	1.11 (0.80; 1.53)	0.99 (0.84; 1.15)	0.85 (0.65; 1.12)	0.90 (0.74; 1.09)	1.15 (1.01; 1.31)*	0.98 (0.93; 1.04)
	Adjusted Incident RR (95% CI) (Region)	1.10 (0.80; 1.52)	0.98 (0.84; 1.14)	0.87 (0.67; 1.13)	1.10 (0.98; 1.25)	0.93 (0.75; 1.14)	0.99 (0.93; 1.04)
80-84	States without Law	3,026	1,144	348	497	3,242	NA
	States with Law	348	2,230	3,026	2,877	132	
	Adjusted Incident RR (95% CI) M1	1.05 (0.89; 1.24)	1.03 (0.87; 1.22)	0.87 (0.75; 1.00)**	0.82 (0.7; 0.96)*	1.36 (0.91; 2.03)	0.96 (0.91; 1.00)**
	Adjusted Incident RR (95% CI) M2	1.05 (0.84; 1.32)	0.98 (0.84; 1.15)	0.82 (0.68; 0.98)*	0.79 (0.67; 0.93)^	1.30 (1.03; 1.64)*	0.96 (0.92; 0.99)*
	Adjusted Incident RR (95% CI) M3	1.05 (0.83; 1.32)	0.97 (0.84; 1.14)	0.84 (0.70; 1.01)**	0.81 (0.68; 0.96)*	1.28 (1.03; 1.59)*	0.96 (0.92; 1.00)**
85 +	States without Law	2,491	867	266	358	2,647	NA
	States with Law	296	1,920	2,521	2,429	140	
	Adjusted Incident RR (95% CI) M1	0.97 (0.82; 1.15)	1.13(0.98; 1.32)**	0.97 (0.82; 1.16)	0.98 (0.83; 1.15)	1.53 (1.18; 1.98)^	0.99 (0.94; 1.03)
	Adjusted Incident RR (95% CI) M2	1.02 (0.84; 1.25)	1.10 (0.94; 1.28)	0.96 (0.78; 1.17)	0.94 (0.82; 1.09)	1.48 (1.23; 1.78)^	0.99 (0.95; 1.04)
	Adjusted Incident RR (95% CI) M3	1.02 (0.83; 1.25)	1.09 (0.94; 1.26)	1.00 (0.81; 1.22)	0.99 (0.84; 1.15)	1.43 (1.20; 1.71)*	1.00 (0.95; 1.04)

*p<0.05; **p<0.10; ^p<0.01

M1- Adjusted for the natural log of licensed drivers in each specified age-cohort, and patient's gender and urban or rural location. Also adjusted for state's primary seat-belt enforcement law, state unemployment rate, annual state total precipitation, state per capita fuel consumption, access to trauma centers, urban speed limits. The dependent variable is the count of MV-fatal crashes of drivers per specified age-cohort. Confidence intervals were estimated based on a GEE autoregressive first order correlation structure at the state level based and results reported are based on empirical standard error estimates.

M2 - Also adjusted for regional similarities.

M3 - Also adjusted for the State's number of fatal crash drivers 55 – 59.

3.5 DISCUSSION

This study highlights the effect of state licensing requirements and physician reporting requirements on older driver safety, as measured by older driver fatal crash involvement. This comprehensive examination of older driver fatal crashes among states with different licensing requirements is based on the assumption that regression models used are appropriately specified without omissions of other major covariates or confounding elements. The models specifications used aim to adjust for state and person-level factors thought to influence crash rates as well as adjust for unobservable state differences by inclusion of crash rates for driver's ages 55 to 59. Similar approaches have been previously published (Grabowski, et al., 2004a; Grabowski & Morrisey, 2001; Houston, 2007; Masten, Foss, & Marshall, 2011). It is of importance to note that results across model specifications, including when adding crash rates of drivers 55 to 59 to adjust for state factors otherwise not accounted in our model, remained relatively consistent in significance and effect direction, indicating inconsequential impact of unaccounted heterogeneity between states on model results (Grabowski, et al., 2004a),

Model specifications, those controlling for state covariates, regional differences and within-state crash trends by including crash rates of those 55 to 59 in the analyses, all pointed towards a safety benefit of vision testing at in-person renewal. This is not entirely surprising as previous studies by Levy et al., (1995) and McGwin et al., (2008) highlight the safety benefits of vision screening on older driver safety. Using 1985 to 1989 FARS data for drivers ages 70 and older, Levy et al. (1995) found that state-mandated tests of visual acuity, adjusted for license renewal period, was associated with lower fatal crash risk for senior drivers (RR, 0.93; 95% CI, 0.89; 0.97), similar to the findings for drivers 70 and older reported in this study. Among drivers ages 80 and older in Florida, McGwin et al. (2008) found that visual acuity licensing standard in Florida was associated with a reduced in MVC fatalities among this group (RR, 0.83; 95% CI 0.72-0.98) even when fatal crash rates among all-age occupants increased. Among drivers 80 to 84, our study reports rate ratios ranging from 0.82 (95% CI 0.70; 0.96) in first model specification to 0.81 (95% CI 0.68; 0.96) in the third model, similar to those reported by McGwin et al. (2008). However, one major limitation for the studies above, including the current one is the unclear mechanism by which vision testing impacts crash rates, as there is little clear understanding on the direct role of visual acuity on MVC involvement or driving performance. Some studies have shown that visuo-spatial processing is related to declines in driving-related response time (Zhang, et al., 2007) and that visual depth impact on driving safety and driving performance (C. Owsley & McGwin, 1999) and that visual-perception shows association with aspects of driving performance (West et al., 2003). However, others show that visual field deficiencies are not related to driving performance (Dow, 2011) and that the predictive values of commonly used vision tests for licensing are inconclusive as vision test scores do not adequately explain unsafe driving performance (Bohensky, Charlton, Odell, & Keeffe, 2008). Therefore there is little clarity on the mechanism by which vision testing promotes safety. One possible explanation is provided by Kulikov (2011) who showed that licensing regulations such as vision testing and in-person renewal were major reasons for older driver's decision to reduce or stop driving (Kulikov, 2011b).

Regarding safety benefits of in-person licensing requirements, our study results point, as do those by Grabowski et al. (2004), to the safety benefit of this requirement among the oldest old of drivers (Grabowski, et al., 2004a). While our results report significant association with a lower fatal crash rate among states with in-person license renewal requirement for those ages 80 to 84 (RR 0.82, 95% CI 0.70; 0.95), Grabowski et al. (2004) reports lower fatal crash rates among drivers 85 and older (RR 0.83, 95% CI 0.72; 0.96) as their study groups drivers ages 75 to 84 in one group, thereby making comparisons less direct.

This study is the first study, to our knowledge, that also examines the role of mandated and legally protected physician reporting of at-risk older drivers on older driver fatal crashes. As in some states physicians are legally obligated to report to motor vehicle authorities drivers with conditions that impair their driving, it was hypothesized that fatal crash rates in states with such restrictions would be lower than in states without such reporting. Across all age groups and the various model specifications, legally mandated physician reporting as well as legally protected physician reporting failed to show any statistical significant relationship to older driver fatal crashes. This is surprising as a review of studies by Brown et al., (2004) highlights three studies demonstrating the importance of physician recommendations on driving cessation among older adults (Brown & Ott, 2004). As noted by Brown, a study by Drickamer et al. (1993) showed that the overwhelming majority of surveyed physicians discuss driving with their patients (Drickamer & Marottoli, 1993). A separate study by Persson (1993) showed that a quarter of interviewed older drivers had stopped driving based on the advice of their physician (Persson, 1993). Furthermore, a study on driving privilege outcomes among older drivers reported to the Oregon department of motor vehicles showed that only 10% of those reported to the Oregon DMV regained driving privileges following testing (K. M. Snyder & Ganzini, 2009). Based on these understandings, mandated physician reporting states were expected to have lower fatal crash rates, although a Canadian study of cardiac illness reporting found that such reporting had a negligible impact on crashes (Simpson, et al., 2000a). Some factors that may explain this lack of association is that physicians may be unaware of reporting requirements in their state or may attempt to avoid harming their rapport with their patient (Eby & Molnar, 2010) or that physicians are not be adequately trained in detecting driving-related conditions (Aschkenasy, et al., 2006b; Johansson, et al., 1996). Other have argued that mandated physician reporting may have let patients to hide potentially dangerous conditions from their physicians for fear of losing licenses (Aschkenasy, et al., 2006b; K. Snyder & Bloom, 2004).

With regard to results for road-testing, our study results point towards an increase crash risk in states with road testing for older drivers. At least one model showed increased crash rates among drivers ages 75 to 79 (RR 1.15; 1.01; 1.31) and two or more models showed increased fatal crash rates among those 80 and older. Although using different age groups, Grabowski et al. (2004) showed similar rates for those 75-84 with regard to road testing (RR 1.13; 95% CI 1.00-1.27). These results may be due to the low number of states with road testing requirements (2) making estimates unreliable as other studies have shown that mandatory assessment that may include road testing is not associated with crash rates in Australia (Langford, Fitzharris, Koppel, & Newstead, 2004). Another interpretation is that, as shown by Baldock et al. (2006), older drivers may not avoid difficult driving situations and overestimate their driving performance even when tested to perform poorly on on-road test (Baldock, et al., 2006).

This study has a number of limitations. One drawback of this study is that it relies on fatality data (FARS) that only capture MVC-related deaths and omit non-fatal crashes, the vast majority of crashes. Also, most crashes among older adults occur at low speeds that are injurious but may not be fatal (NHTSA, 2009) and FARS based analyses completely exclude MV-related injuries that require hospitalization but do not result in death. Furthermore, although the examined period spans 6 years, for a number of licensing requirements, notably on-road testing, only limited numbers of observations were available due to the low number of states with such requirements, making comparisons more difficult. A third limitation, that is inherent in many transportation related examinations and highlighted elsewhere, is the difficulty in controlling for state-specific confounding factors not immediately identified.

In conclusion, across the 3 modeling approaches, vision testing at in-person renewal was related to significantly lower fatal crash rates among four of the six age groups examined with other state licensing laws such as in-person renewal and road testing indicated borderline association with fatal crash rates among select groups. Interestingly, physician reporting mandates, mandated or legally protected, and length of licensing renewal lacked any independent association with fatal crash rates.

4.0 ROLE OF DRIVER LICENSING AND PHYSICIAN REPORTING LAWS ON OLDER DRIVER MVC HOSPITALIZATIONS

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4.1 ABSTRACT

Objective: To determine the effect of state licensing provisions and state risky driver physician reporting requirements on older driver motor vehicle crash related hospitalizations. Study is guided by the hypothesis that states with stricter licensing restrictions and mandatory physician reporting would yield lower crash related hospitalization rates.

Methods: Retrospective data on older driver hospitalizations due to motor vehicle crashes was obtained from the State Inpatient Databases (SID) from the Agency for Healthcare Quality and Research (AHRQ) for the years 2004 to 2009. Older drivers ages 60 and older were selected (n= 136,987; 53.9% male) with an additional 37,079 hospitalized drivers 55 to 59 identified for comparison purposes. Incidence rates of crash related hospitalizations were estimated using three Generalized Estimating Equation count models (negative binomial) to examine the effect of state licensing law provisions, including in-person renewal, vision testing, road testing and length of renewal cycle, and risky driver physician reporting laws that include mandated physician reporting and legally protected reporting laws. Models adjust for person-level covariates that include driver gender, urban/rural crash location and state-level covariates that include number of licensed drivers per age group, state primary seat-belt enforcement laws, state unemployment rate, annual state total precipitation, state per capita fuel consumption, access to trauma centers and urban speed limits.

Results: Vision testing at renewal showed significant association with a lower hospitalization rate for hospitalized drivers ages 65 to 74. For those ages 70 to 74, vision testing was significantly associated with an incidence rate ratio [IRR] of 0.76 (95% Confidence interval [CI] 0.62; 0.93) when adjusting for other covariates. For drivers ages 75 to 84, vision testing was only significant in the first model specification, without adjusting for regional differences and crash

rates of driver's ages 55 to 59 in the respective states. Length of licensing renewal and road testing were not found to be related to a statistically different hospitalization rate in majority of the age groups examined, with the exception of a borderline ($p<0.10$) association for road testing with a lower hospitalization rate among drivers 75 to 79 when adjusting for covariates and regional differences (IRR 0.88, 95% CI 0.77; 1.01) and a similarly borderline lower crash hospitalization rate for states with longer licensing periods for drivers ages 70 to 74 (IRR 0.93, 94% CI 0.85; 1.01). There was no significant association between state mandated physician reporting requirements, legally protected physician reporting requirements with fatal crash rates among groups examined. Similarly in-person renewal was not independently associated with lower crash hospitalization rates.

Conclusions: Vision testing at in-person renewal was related to significantly lower driver crash hospitalization rates among five of the six age groups examined in at least one modeling group. Other state licensing laws such as length of licensing renewal and road testing indicated borderline association with hospitalization rates among select groups. Physician reporting requirements, mandated or legally protected, and in-person renewal lacked any independent association with driver crash hospitalization rates.

4.2 INTRODUCTION

In 2009, some 175,000 adults 65 and older were admitted to emergency departments due to MV related injuries, with another 31,000 further transferred or hospitalized (CDC, 2011). In that same year 4,396 adults 65 and older were killed as drivers of a motor vehicle in-transport (NHTSA, 2011). Since 2001 some 1.4 million older adults have received emergency department (ED) treatment (CDC, 2010) and over 64,000 have died due to motor vehicle (MV) injuries (NHTSA, 2009) and motor-vehicle related hospitalizations and injuries for 2008 alone have resulted in an estimated $3 billion in direct medical cost (Corso, et al., 2006; Naumann, et al., 2010)

Some argue that after teenage males, older adults have the highest per capita MV fatality rate (Morrisey & Grabowski, 2005; NHTSA, 1999) making it the second leading cause of injury death after falls (CDC, 2010). Others show that MV-related injuries result in significant post-crash disability, accounting for 25% of limitations in activities of daily living (ADL) among those with injury-related chronic disabilities (Guerrero JL, 1999). And by 2050 there will be some 88.5 million older adults, representing 25% of the driving population, an increase from the current 16.1% of the driving population (US Census, 2009). Following current trends it is expected that more than 80% of older adults will be licensed to drive.

Additionally while studies show that age-related declines in vision and cognitive functioning as well as physical changes, may affect some older adults' driving performance (C Owsley, 1999), age is only mildly correlated with driving performance in models that adjust for co-morbid conditions (Grabowski, et al., 2004a). Others have demonstrated that only older drivers that drive fewer than 1900 annual miles (3000 km) are at increased risk of crash

(Langford, et al., 2006) or have shown that increased fatality rates among older drivers may be due their inherent fragility (Li, et al., 2003).

Nevertheless, state governments, to the dismay of many older drivers, have introduced different requirements for ensuring the safety of the driving public, including that of the older driver. A number of states now mandate physician reporting of patients with driving-related medical conditions and have introduced stringent age-based licensing screening criteria that require in-person renewals, vision tests, physician reports, written and road tests as well as a shorter license renewal period. The purpose of this study is to examine the role of state driver licensing laws and physician reporting requirements on older driver crash hospitalizations. Findings will contribute to the safety and wellbeing of older adults by determining appropriate licensure policies, the optimal role of physicians in licensing.

4.3 METHODS

4.3.1 Study population

This study uses hospital admission data of older adult drivers from US Hospitals, from 2004 to 2009. This information is made available through the State Inpatient Databases (SIDs) of the Agency for Healthcare Quality and Research (AHRQ) Healthcare Cost and Utilization Project (HCUP), a public-private partnership. Details on how the SID data are collected can be found on the AHRQ website (Agency for Healthcare Research and Quality, 2008). Adult drivers hospitalized due to motor-vehicle crashes were identified based on discharge abstract ICD-9-CM External Causes of Injury Codes (E-codes) E810-E819 with a fourth digit of .0 (driver) in any of the first four E-code fields. The SIDs contains patient information from standardized discharge abstracts that include demographic and clinical data at the patient level and information at the hospital level. Over the 6 years of data available for the study, a total of 136,987 drivers 55 and older, hospitalized due to motor-vehicle crash, were identified. In line with other hospital based studies, to avoid double counting, hospitalized adults were dropped if their incoming source was another hospital or long-term care center.

Since state hospitalization data sharing is voluntary, not all state hospitalization data were available for the whole period covered. There were 37 states reporting in 2004 and 2005, 39 in 2006, 40 in 2007, 32 in 2008 and 44 in 2009, resulting in 229 state-year observations. The population of interest was drivers ages 60 and older and hospitalized drivers ages 55 to 59 were used as a comparison group to adjust for the influence of non-accounted factors in hospitalization rates between states.

4.3.2 Study variables

Information on state requirements for mandatory physician reporting of at-risk drivers and legal protection of reporting physicians was obtained from Physician's Guide to Assessing and Counseling Older Drivers, 1st and 2nd editions, published in 2004 and 2010 by the American Medical Association (AMA) and the National Highway Traffic Safety Administration (NHTSA), state DMV's, the AAA Foundation's License Policy and Practices Database(AAA, 2011). Data on older driver state licensing requirements were obtained from the AAA Foundation's License Policy and Practices Database (AAA, 2011), the Insurance Institute for Highway Safety (IIHS) older drivers, licensing renewal provisions (IIHS, 2011b), state DMV's, and the AMA/NHTSA guides (AMA, 2004, 2010). Data for annual state and age specific data on driver licensing was obtained from the US Federal Highway Administration's (FHWA) annual Highway Statistics publications (FHWA, 2004-2009), whereas data on state's age specific population was obtained from the US Census Bureau (Census, 2011). These data served as denominator counts for analyses conducted.

Data on adjusting variables were collected from a number of sources. Seatbelt requirements were obtained from the IIHS belt-use laws depository (IIHS, 2011d). Urban and rural speed limits were also obtained from the IIHS (IIHS, 2011c). Data on annual total state precipitation was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NOAA, 2011) whereas data on annual state motor-fuel consumption was obtained from the US Federal Highway Administration's annual Highway Statistics publications 2004-2009 (FHWA, 2004-2009). And data on 2009 average annual vehicle miles traveled (VMT) was obtained by the 2009 National Household Transportation Survey (FHWA, 2011). Data on trauma center access reflects access to Trauma I and II centers within 45 minutes as collected in 2005 by Branas and colleagues (Branas, et al., 2005). Data on annual state unemployment rates were obtained from the US Department of Labor's Bureau of Labor Statistics (BLS)(BLS, 2011). The University of Pittsburgh Institutional Review Board classifies this study as exempt. All analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, North Carolina).

4.3.3 Parameterization of variables

Quarterly counts of motor-vehicle crash related hospitalizations by state and age groups, were extracted from annual state hospitalization databases, with drivers grouped into 7 age cohorts (55-59, 60-64, 65-69, 70-74, 75-79, 80-85, 85 and older). Given the changes in state requirements at varying intervals, it is argued that smaller age-groups will achieve a more accurate representation of the various driving requirements. Since mandated physician reporting of a broad category of at-risk drivers may substantially influence the driving population of a state and subsequently the crash-related hospitalizations of drivers in that state, a variable indicating this state characteristic was created. A binary variable denoting whether a state requires physician reporting was created, with 3 states participating in HCUP mandating physician reporting of at-risk drivers that go beyond narrow definitions such as epilepsy or those characterized by loss of consciousness. Therefore only states with broad definitions of at-risk drivers that mandated physician reporting were categorized as such. A second binary variable was created to denote whether a state provided legal protection, such as immunity, to reporting physician, regardless if reporting was required by law. Among HCUP participating states, 27 states provided such protection.

Variables indicating state licensing requirements thought to influence driver safety were also generated for each age group to best reflect the licensing requirements for that age cohort. One such requirement is that drivers present in-person for license renewal at least once within two or three renewal cycles, rather than using other renewal modes such as mail, phone or the web. This is thought to allow DMV personnel to assess driver's driving fitness. A binary variable indicating whether such requirement was in place was generated. Only 5 states did not require in-person renewals. Other licensing requirements applied include road test at licensing renewal and vision testing. From participating states, only two states required a road test for license renewal. Among analyzed States, 36 states required vision acuity testing as a precondition to continued driving, when presenting in-person for license renewal Furthermore, state license renewal periods, measured in years, was also included in model. Renewal period indicating the license validity length, varied considerably among those 60 to 70, with less variability among the older age groups.

In addition to state physician reporting requirements and licensing requirements, 8 other variables related to older driver safety were generated to be included as adjusting variables. The state's seat-belt enforcement requirements were reflected in a binary variable indicating whether a state practices primary seat-belt enforcement, whereby being unbelted is sufficient reason for police enforcement. Another element that may influence the likelihood of crash-related hospitalization is state's weather conditions. States annual total precipitation was used to represent this element in the model. A continuous variable reflecting precipitation was computed. Adverse weather conditions, especially rain, are considered road hazards for many drivers, and older drivers are known to avoid driving during inclement weather, hence the need to adjust for this factor given its variation across the United States (Kostyniuk & Molnar, 2008; Okonkwo, et al., 2008). A binary variable reflecting the speed limits in State's urban areas was included as well, indicating whether the speed limit in urban roads was equal or higher than 60 mph.

Quarterly frequencies of driver hospitalizations extracted from state hospitalization databases also include variables indicating patient's gender. Additionally, an indicator variable for patient's rural or urban location was also extracted from hospitalization data, and included in the analyses as a control variable. Furthermore, since the comparisons are made at the state-quarter level, that helps adjust for any differences for both hospitalizations and crashes between states that may follow a seasonal trend. Similarly we also created a variable to indicate state's region, as to control for any region-wide characteristics in hospitalizations and crashes. States were separated into four regions (West, Midwest, Northeast and South) based on US Census Bureau Regional divisions (Census, 2009).

To adjust for differences in emergency care access between states among older adults involved in crashes, a variable denoting access to trauma centers was included. This variable indicates the proportion of the state's population that have access to Trauma I and II centers within 45 minutes of their residence as collected in 2005 (Branas, et al., 2005). Furthermore, to adjust for any state differences in road infrastructure, safety features of on-road vehicle fleet and other factors (Evans, 1991; Ruhm, 1996), a variable indicating annual real state Gross State Product (GSP) per capita income was included. To further adjust for any differences in driving exposure, a variable indicating states' annual fuel consumption per capita was entered in the model (FHWA, 2004-2009). Finally, a natural log transformed variable for each age-cohort denoting the number of licensed drivers per state and year was computed to serve as a measure of exposure, offset variable, for analyses (UCLA, 2011). In SAS, exposure measure is log transformed prior to inclusion as an offset variable (Pedan, 2001; UCLA, 2011). For hospitalized driver analyses, it is the annual age-cohort specific total licensed driver counts that serve as the measure of exposure.

4.3.4 Statistical analyses

Differences in motor vehicle crash (MVC) related hospitalization rates among older adult drives in states with different licensing requirements were examined using three age-specific Generalizes Estimating Equations (GEE) negative binomial regression models, detailed below. Due to the characteristics of our data, namely state-quarter level counts and a data-set with higher variability than expected in a Poisson distribution based model, negative binomial regression was deemed as the most appropriate count information modeling approach. The presented models showed significant over-dispersion for all age-cohort analyses, indicating over-dispersion of the response variable, and indicating lack of fit for a potential Poisson distribution model. The negative binomial regression model is a good way of modeling heterogeneity in populations due to differences in distributions as it accounts for over-dispersion of data (Hilbe, 2008). In order to account for the non-independence of observations, GEE based regression model applies an additional term to the model indicating correlation between observations at the cluster specified. In our case this term is computed using an autoregressive correlation structure, a structure which argues that hospitalizations that occur closer in time have a higher correlation than those with larger time intervals. While GEE based estimates are robust to potential correlation structure misspecification, the auto-regressive structure of correlation of within-cluster observations is most appropriate for our data as they contain a time order component (Hosmer, 2000; Pan, 2001). This approach produces the most conservative standard error estimates and is appropriate given the changing driving environment. In addition to adjusting for the lack of independence between observations at the state-quarter level, this approach also adjust for any seasonality effects on driver hospitalizations, as the time of observation is the annual quarters.

As Zeger, Liang and Albert (1988) note the main feature that distinguishes person-level models from our count-based model is that the regression coefficient presented describes the average population response, in our case driver hospitalizations, to changes in specified independent variables (Zeger, et al., 1988). We further apply a finite sample correction to standard errors. This is done to account for the finite cluster possibilities in our sample, finite number of states that serve as clusters. Furthermore, as our sample accounts for more than 5% of total population, a finite correction is warranted (Cohen, Cohen, West, & Aiken, 2002).

The appropriateness of negative binomial for our data was determined using deviance and scaled deviance from each model. In all analyses deviance and scaled deviance values approximated a chi-square distribution and resulting value (when dividing by degrees of freedom) remained close to 1, indicating a good fit and yielding accurate standard errors for chi-square statistics. The models showed significant over-dispersion for all age-cohort analyses, indicating over-dispersion of the response variable and the lack of fit for a potential Poisson distribution model.

Following this determination, the GEE analyses were requested for each of the age-cohort specific models. At this stage, the quasi-likelihood independent criterion (QIC) was used to inform the best model specification (SAS, 2011). The QIC is based on the Akaike's information criterion (AIC) widely used on other forms of regression, that cannot be directly applied to GEE based estimates due to GEE's non-likelihood based approach (Pan, 2001). Based on this criterion, two non-significant parameters that decreased model fit, namely GDP per state capita and rural urban speed, were removed from the model. It is assumed that the final models specified adequately controlled for these two aspects by maintaining a patient's urban/rural location and the state's unemployment rates.

4.3.5 Model specifications

Model 1 (M1): The first model specification examines the number of driver hospital admissions for each of the 7 age cohorts, using multivariate negative binomial regression. The outcome measure is the number of hospitalized adults per age-group specified, with the set of independent variables including mandatory physician reporting, legally protected physician reporting, at least one in-person renewal within 3 renewal cycles, states' in-person only renewal requirements and renewal period. A number of adjusting variables such as patient's gender, patient's urban or rural location, state's primary seat-belt enforcement requirements, annual precipitation, fuel consumption, unemployment rate, proportion of state's population with 45 minute access to trauma 1 and 2 centers and variable indicating state's urban speed limit over 60 mph. Road testing was only included for models with ages 75 and older. **Model 2 (M2):** The second model specification includes the set of variables from the first model with the additional inclusion of a design variable for region. **Model 3 (M3):** The final model specification results is one that in addition to the set of variables included in model 1 and 2, also includes the hospitalization counts of drivers 55 to 59 in the model. This approach, also called Differences-in-Differences (DD) estimation, treats hospitalizations of drivers 60 and older as cases that are under the influence of the state laws and regulations examined in this study and the hospitalizations of drivers under 60 years old as controls, as drivers that are not directly influenced by the age-based licensing and medical reporting laws. By including the quarterly hospitalizations of those under 60, this approach allows for the estimation of the difference in effect of the state laws on the difference in hospitalization rates between the groups, (Ruhm, 1996). This follows the assumption that the difference between the hospitalizations of the two groups within each state quarter will remain constant if age-based licensing and reporting requirements have no impact on the hospitalization trends of targeted older drivers. This approach also has the effect of using the population of hospitalized drivers 55 to 59 as a way to adjust for the heterogeneity of the populations being compared and is in line with previous studies (Grabowski, et al., 2004a). A main assumption of this DD estimation approach is that there should be no other major factor that affects the difference in the hospitalization counts between those under 60 and older than 60 at the state-quarter level (Thomas S. Dee, 2001; Gruber, 1994).

4.4 RESULTS

4.4.1 Results

Characteristics of hospitalized older drivers indicate that among those drivers 60 and older, some 46.1% are hospitalized female drivers, although the licensing rate of female drivers is significantly lower than male drivers, especially for ages 75 and older. The majority of hospitalized drivers are from urban areas (79%) and drivers ages 60 to 64 account for the highest proportion (22.7%) of those hospitalized. Some 38,432 hospitalized drivers ages 55 to 59 are not included in the demographic results below.

Table 8: Hospitalized driver demographics

	No.	%
MV hospitalized older drivers		
60-64	31,087	22.69
65-69	24,862	18.15
70-74	23,007	16.80
75-79	22,847	16.68
80-84	20,377	14.88
85+	14,807	10.81
Patient Gender		
Female	63,001	46.07
Male	72,862	53.93
Patient Location		
Urban	107,610	79.14
Rural	28,367	20.86

Table 9 presents hospitalization characteristics for MVC-related hospitalized drivers ages 60 and older. The average length of stay was 6.2 days, with an estimated 9 diagnoses and approximately 2 procedures per hospitalized driver. The top 3 diagnoses included a group of fractures to include fractures of vertebral column, pelvis, rib and other factures, denoted as other fractures in Table 9, accounting for 23% of all diagnoses, followed by lower limb fractures (10%) and intracranial injuries (15%) with the majority of hospitalized drivers discharged home (51%) following stay, 30% transferred to other health facilities and some 4.5% having died while in hospital. Private health insurance and Medicare were the two most common forms of payment, accounting for 57% and 29% of payment type, respectively.

Table 9: Patient hospitalization characteristics

	No.	%
Length of Stay (Mean Days)	6.23	NA
Average No. of Patient Diagnoses	8.70	NA
Average No. of Patient Procedures	2.15	NA
Principal Diagnoses		
Other fractures	31,430	22.9
Fracture of lower limb	14,219	10.4
Intracranial injury	20,072	14.6
Crushing injury or internal injury	14,082	10.3
Fracture of upper limb	7,352	5.3
Superficial injury; contusion	7,440	5.4
Syncope	4,909	3.5
Other injuries due to external causes	3,667	2.6
Fracture of neck of femur (hip)	2,537	1.8
Skull and face fractures	2,074	1.5
Disposition of patient		
Routine Discharge	69,735	51.0
Transfer: Short Term Hospital	5,384	3.9
Transfer: other type of facility	40,841	29.8
Home health care	13,484	9.8
Against medical advice	986	0.7
Died in hospital	6,177	4.5
Discharged alive, destination unknown	90	0.1
Primary expected payer		
Medicare	39,721	29.24
Medicaid	2,049	1.51
Private Insurance/HMO	79,651	58.64
Self-pay	5,358	3.94
No Charge	187	0.14
Other	8,870	6.53

Table 10 describes the length of state-quarter observations for each major physician reporting and licensing requirements. From a total of 916 state-quarter observations, mandatory physician reporting was in effect for 48 quarters, reporting in states that provide legal protection or immunity to reporting physicians was in effect for 540 state-quarters, at least one in-person renewal within two or three renewal cycles, and road testing were in effect, 824 and 48 state-quarters, respectively. Regarding vision testing, vision-testing at in-person renewals was in effect for 756 state-quarters, or 82.5 % of examined quarters.

Table 10: Number of State-Quarter Observations

	State-Quarters	
	No.	% of total
Mandatory physician reporting	48	5.24
Physician reporting (LP)	540	58.95
In-person renewal*	824	89.96
Vision testing at renewal	756	82.53
Road test	48	5.24
Urban speed limit $\geq$ 60 mph	684	74.67
Primary seatbelt	432	47.16
Total	916	

* at least one in-person renewal within 2 or 3 renewal cycles

Table 11 presents the pooled driver hospitalization rates based on 2004-2009 state population person-years and 2004-2009 state licensed population person-years. Based on the number of licensed drivers per age group, drivers 55-59 had 19.82 hospitalizations due to motor-vehicle crashes per 100,000 licensed person-years, and comparable 20.91 hospitalizations per 100,000 person-years. This rate increased to 29.3 hospitalizations per 100,000 licensed person-years and 25.5 per 100,000 person-years for drivers 70-74, but was markedly elevated among drivers 85 and older using both measures of exposure. Those 85 and older had a rate of 49.4 hospitalizations per 100,000 licensed person-years drivers and 27.5 per 100,000 person-years.

Table 11: 2004-2009 Driver Hospitalization Rates

Age Group	Hospitalized Drivers	Person-years (PY)	Person-years (Licensed)	Driver Hospitalization Rate per 100,000 Licensed PY	Driver Hospitalization Rate per 100,000 Person Years
55-59	37,079	187,088,729	177,324,051	19.82	20.91
60-64	31,087	146,306,772	139,283,316	22.32	21.25
65-69	24,862	111,471,291	102,889,360	24.16	22.30
70-74	23,007	90,265,123	78,640,390	29.26	25.49
75-79	22,847	77,162,186	62,925,933	36.31	29.61
80-84	20,377	59,621,191	44,029,240	46.28	34.18
85+	14,807	53,798,693	29,956,387	49.43	27.52

Table 12 presents a similar rate examination using the number of vehicle miles traveled (VMT) as the measure of exposure. As vehicle miles traveled (VMT) by age was only available for 2009 from the 2009 National Household Travel Survey, rates are only calculated for 2009 fatalities. On a per 100 million VMT basis, drivers 55-59 have the lowest rate of motor-vehicle related crash hospitalizations, increasing from 3.2 hospitalizations per 100 million miles traveled among this age group to 10.6 hospitalizations per 100 million VMT for those 70-74 and to 22.3 for those over age 85. As when using licensed drivers and population size, fatal crash involvement appears to markedly past age 75.

Table 12: 2009 Driver Hospitalization Rates per VMT

Age Group	Hospitalized Drivers	Licensed Drivers	Average VMT per group	Estimated VMT	Hospitalization Rate per 100 Million Miles Traveled
55-59	7,190	17,265,661	12,795	220,909,988,736	3.25
60-64	6,160	14,511,411	11,428	165,831,906,371	3.71
65-69	4,989	10,606,519	10,140	107,550,314,790	4.64
70-74	4,243	7,677,953	7,964	61,149,751,416	6.94
75-79	4,089	5,846,475	6,952	40,644,635,735	10.06
80-84	3,837	4,222,747	5,336	22,532,451,310	17.03
85+	3,009	3,135,103	4,299	13,477,807,797	22.33

Table 13 reports unadjusted hospitalization incidence rate ratios (IRR) based on number of licensed person-years for the study age groups according to licensing requirements examined. States with mandatory physician reporting had higher hospitalizations rates starting with drivers ages 75 and older compared to states without mandated physician reporting, however only among drivers ages 85 and older were rate differences markedly different (123.8 vs. 95.6 per 100,000 licensed person-years). Hospitalization rates were similar across age-groups when comparing states with legally protected physician reporting. States with in-person renewal requirements and states with vision testing at renewal had markedly lower unadjusted rate ratios than those without those requirements. For example the rate was 71.3 hospitalizations per licensed person-years in states with in-person renewal in contrast to 82.9 hospitalizations per licensed person-years in states without in-person renewal requirements [RR 0.86]. Unadjusted rate ratios for road testing requirements indicated a lower hospitalization rate among states with these requirements for all three age-groups for which at least once state has such a requirement. Statistical model based adjusted rate ratios, adjusting for person and state-level covariates, are presented in Table 14.

Table 13: Unadjusted Rate Ratios

	Mandatory Physician Reporting			Physician reporting (LP)			In-person Renewal			Vision Testing			DVM Road test		
Age group	**Yes**	**No**	**Rate Ratio**	**Yes**	**No**	**Rate Ratio**	**Yes**	**No**	**Rate Ratio**	**Yes**	**No**	**Rate Ratio**	**Yes**	**No**	**Rate Ratio**
55-59	42.8	43.4	0.99	43.8	42.5	1.03	42.9	46.6	0.92	42.2	51.7	0.82			
60-64	42.8	44.9	0.95	44.4	45.1	0.98	44.1	48.5	0.91	43.4	53.6	0.81			
65-69	47.4	48.5	0.98	47.6	49.7	0.96	47.6	54.3	0.88	47.0	58.1	0.81			
70-74	57.1	58.7	0.97	58.3	59.0	0.99	57.4	67.0	0.86	56.7	71.4	0.79			
75-79	75.1	72.2	1.04	72.1	73.6	0.98	71.3	82.9	0.86	70.8	85.1	0.83	49.5	73.8	0.67
80-84	97.2	91.9	1.06	92.9	91.8	1.01	91.5	100.5	0.91	90.5	105.9	0.85	76.5	93.2	0.82
85+	123.8	95.6	1.30	99.7	97.1	1.03	97.6	107.3	0.91	99.1	97.0	1.02	63.3	100.9	0.63

Rates calculated based on per 100,000 licensed person-years

4.4.2 Model results

Examining mandatory physician reporting laws, neither of the three model specifications showed statistically significant association with hospitalization rates in any of the age groups examined, when including other independent predictors and covariates in the model. Similarly, across all model specifications there was no association between legally protected physician reporting requirements and MVC-related hospitalization rates, represented in Incident Rate Ratios (IRR).

State requirement for in-person renewals was another factor that showed no significant association with hospitalization rates among any of the age groups across the three model specifications, including when adjusting for regional differences as well as crash hospitalization trends among those 55 to 59. Contrary to in-person license renewal requirements, states with vision testing requirements when renewing in-person showed a consistent statistical association with a lower hospitalization rate for 5 of the 6 age-groups. Among drivers 60-65 this state licensing provision was associated with an IRR of 0.77 (95% CI 0.62; 0.94) and IRR 0.77 (95% CI 0.68; 0.98) according to the first and second model specification, respectively. An incidence rate ratio of 0.88 (95% CI 0.78; 0.98) was obtained in the third specification, adding hospitalization rates of those 55-59 into the model. Vision testing at renewal showed significant association with a lower hospitalization rate in two of three models for those drivers 65 to 74. For those 70 to 74, vision testing was significantly associated with lower hospitalization rates, IRR 0.78 (95% CI 0.62; 0.98). Also vision testing was significant according to the first model for those 75 to 84, with IRR 0.75 (95% CI 0.62; 0.93) for those ages 70 to 74 and IRR 0.83 (95% CI 0.67; 0.97) for those ages 80 to 84. Vision testing was not a significant predictor of hospitalization rates among those ages 85 and older in any of the three specifications.

Road testing was only included in models for drives ages 75 and older, as this requirement does not apply to other age groups. Road testing showed borderline significant association at an alpha of 0.10 in the 2nd model specification controlling for regional differences, yielding an adjusted rate ratio of 0.88 (95% CI 0.77; 1.01). It also showed an elevated hospitalization risk among those ages 85 and older when adjusting for hospitalization trends of those 55 to 59 as well as regional differences, yielding a rate ratio of 1.19 (95% CI (1.05; 1.35). License renewal length showed no significant relationship with hospitalization rates, with the exception of a borderline statistically significant higher hospitalization rate among states with shorter license renewal periods among drivers 70 to 74 [IRR 0.93; 95% CI 0.85; 1.01] .

Table 14: Negative binomial models - Hospitalized drivers according to state laws

Age		Mandatory physician reporting	Physician reporting (Protected)	In-person renewal	Vision testing when in-person	Road test	Renewal period
60-64	States without Law	25,757	10,448	3,816	6,875	Na	Na
	States with Law	4,258	19,567	26,199	23,140		
	Adjusted Incident RR (95% CI) M1	0.96 (0.79; 1.17)	1.02 (0.84; 1.25)	0.87 (0.67; 1.13)	0.77 (0.62; 0.94)*		0.95 (0.77; 1.18)
	Adjusted Incident RR (95% CI) M2	0.96 (0.74; 1.23)	1.01 (0.84; 1.21)	0.87 (0.67; 1.14)	0.77 (0.61; 0.98)*		0.95 (0.75; 1.20)
	Adjusted Incident RR (95% CI) M3	0.88 (0.71; 1.10)	0.99 (0.87; 1.12)	0.92 (0.77; 1.11)	0.88 (0.78; 0.98)*		0.91 (0.76; 1.10)
65-69	States without Law	20,710	8,443	3,122	5,611	Na	Na
	States with Law	3348	15,615	20,936	18,447		
	Adjusted Incident RR (95% CI) M1	1.03 (0.83; 1.29)	0.98 (0.81; 1.20)	0.88 (0.66; 1.16)	0.78 (0.62; 0.98)*		0.97 (0.63; 1.49)
	Adjusted Incident RR (95% CI) M2	1.03 (0.79; 1.35)	0.98 (0.82; 1.17)	0.90 (0.68; 1.19)	0.80 (0.61; 1.03)**		0.96 (0.58; 1.57)
	Adjusted Incident RR (95% CI) M3	0.95 (0.75; 1.20)	0.95 (0.84; 1.07)	0.97 (0.82; 1.14)	0.92 (0.78; 1.08)		0.95 (0.66; 1.37)
70-74	States without Law	19153	7,672	2,946	5,351	Na	Na
	States with Law	2946	14,427	19,153	16,748		
	Adjusted Incident RR (95% CI) M1	1.00 (0.82; 1.23)	1.05 (0.86; 1.27)	0.82 (0.65; 1.05)	0.76 (0.62; 0.93)*		0.75 (0.52; 1.09)
	Adjusted Incident RR (95% CI) M2	1.00 (0.78; 1.27)	1.06 (0.88; 1.27)	0.86 (0.67; 1.09)	0.81 (0.63; 1.03)**		0.93 (0.85; 1.01)**
	Adjusted Incident RR (95% CI) M3	0.90 (0.73; 1.12)	1.03 (0.91; 1.15)	0.92 (0.81; 1.06)	0.90 (0.79; 1.03)		0.78 (0.56; 1.08)
75-79	States without Law	19,061	7,728	2,980	5,336	21,260	Na
	States with Law	2,987	14,320	19,068	16,712	788	
	Adjusted Incident RR (95% CI) M1	1.02 (0.81; 1.28)	1.03 (0.85; 1.26)	0.86 (0.69; 1.08)	0.81 (0.65; 0.99)*	0.87 (0.75; 1.01)	0.80 (0.57; 1.13)
	Adjusted Incident RR (95% CI) M2	1.03 (0.77; 1.38)	1.04 (0.86; 1.26)	0.90 (0.72; 1.12)	0.85 (0.66; 1.08)	0.88 (0.77; 1.01)**	0.76 (0.54; 1.08)
	Adjusted Incident RR (95% CI) M3	0.95 (0.72; 1.25)	1.00 (0.87; 1.16)	0.95 (0.82; 1.1)	0.93 (0.79; 1.09)	1.01 (0.9; 1.13)	0.84 (0.63; 1.12)

Table 14: Continued

80-84	States without Law	16,917	6,828	2,638	4,859	18,947	Na
	States with Law	2,725	12,814	17,004	14,783	695	
	Adjusted Incident RR (95% CI) M1	0.97 (0.77; 1.21)	1.03 (0.85; 1.24)	0.93 (0.72; 1.20)	0.83 (0.67; 0.97)*	0.94 (0.79; 1.12)	0.86 (0.65; 1.13)
	Adjusted Incident RR (95% CI) M2	0.99 (0.74; 1.31)	1.03 (0.86; 1.24)	0.94 (0.72; 1.23)	0.84 (0.66; 1.06)	0.93 (0.78; 1.11)	0.85 (0.66; 1.09)
	Adjusted Incident RR (95% CI) M3	0.90 (0.70; 1.15)	0.99 (0.87; 1.13)	1.02 (0.86; 1.20)	0.92 (0.80; 1.06)	1.12 (0.97; 1.28)	0.93 (0.76; 1.14)
85 +	States without Law	12,136	4,750	1,979	3,483	13,729	Na
	States with Law	2,104	9,490	12,261	10,757	511	
	Adjusted Incident RR (95% CI) M1	1.00 (0.84; 1.20)	1.07 (0.9; 1.27)	0.86 (0.67; 1.09)	0.87 (0.72; 1.04)	1.00 (0.81; 1.24)	0.94 (0.75; 1.17)
	Adjusted Incident RR (95% CI) M2	0.99 (0.79; 1.23)	1.10 (0.93; 1.29)	0.86 (0.66; 1.14)	0.90 (0.72; 1.12)	1.02 (0.84; 1.25)	0.91 (0.75; 1.11)
	Adjusted Incident RR (95% CI) M3	0.92 (0.76; 1.11)	1.07 (0.96; 1.19)	0.97 (0.82; 1.15)	1.01 (0.91; 1.11)	1.19 (1.05; 1.35)*	0.94 (0.83; 1.07)

*p<0.05; **p<0.10;

M1- Adjusted for the natural log of licensed drivers in each specified age-cohort, and patient's gender and urban or rural location. Also adjusted for state’s primary seat-belt enforcement law, state unemployment rate, annual state total precipitation, state per capita fuel consumption, access to trauma centers, urban speed limits. The dependent variable is the count of MV-crash hospitalizations of drivers per specified age-cohort. Confidence intervals were estimated based on a GEE autoregressive first order correlation structure at the state level based and results reported are based on empirical standard error estimates.

M2 - Also adjusted for regional similarities.

M3 - Also adjusted for the State's number of hospitalized drivers 55 - 59

4.5 DISCUSSION

This study highlights the effect of major state licensing and physician reporting requirements on older driver safety, as measured by older driver motor vehicle crash-related (MVC) hospitalizations. This comprehensive examination of older MVC-related hospitalizations among states with different licensing requirement is based on the assumption that regression models used are appropriately specified without omissions of significant covariates or confounding elements. The models specifications used aim to adjust for state and person-level factors thought to influence hospitalization rates as well as adjust for unobservable state differences by inclusion of crash rates for drivers' ages 55 to 59. Similar approaches have been published previously (Grabowski, et al., 2004a; Grabowski & Morrisey, 2001; Houston, 2007; Masten, et al., 2011). It is of importance to note that results across model specifications, including when adding crash rates of drivers 55 to 59 to adjust for state factors otherwise not accounted in our model, remained relatively consistent in significance and effect direction, indicating insignificant impact of unaccounted heterogeneity between states on model results (Grabowski, et al., 2004a),

Model specifications, those controlling for state covariates, regional differences and within-state crash trends by including hospitalization rates of those 55 to 59, pointed towards a safety benefit of vision testing at in-person renewal for drivers ages 60 to 74, and less clearly among those ages 75 to 79. This is not entirely surprising as previous studies by Levy et al., (1995) and McGwin et al., (2008) highlight the safety benefits of vision screening on older driver safety. Using 1985 to 1989 FARS data for drivers ages 70 and older, from, Levy et al. (1995) found that state-mandated tests of visual acuity, adjusted for license renewal period, was associated with lower fatal crash risk for senior drivers (RR, 0.93; 95% CI, 0.89; 0.97), similar to the findings for drivers ages 70 to 74 reported in this study. Among drivers ages 80 and older in Florida, McGwin et al. (2008) found that visual acuity licensing standard in Florida was associated with a reduced in MVC fatalities among this group (RR, 0.83; 95% CI 0.72-0.98) even when fatal crash rates among all-age occupants increased. Among drivers 80 to 84, our study reports non-significant association between vision testing and hospitalization rates. However, one major limitation for all the above studies, including the current one, is the unclear mechanism by which vision testing impacts crash hospitalizations, as there is little clear understanding on the direct role of visual acuity on MVC involvement or driving performance. Additionally while studies have shown that visuo-spatial processing is related to declines in driving-related response time (Zhang, et al., 2007) and that visual depth impacts driving safety and driving performance (Owsley & McGwin, 1999) others show that visual field deficiencies are not related to driving performance (Dow, 2011). Furthermore, some argue that the predictive values of commonly used vision tests for licensing are inconclusive as vision test scores do not adequately explain unsafe driving performance (Bohensky, et al., 2008). One possible explanation is provided by Kulikov (2011) who showed that licensing regulations such as vision testing and in-person renewal were major reasons for older driver's decision to reduce or stop driving (Kulikov, 2011b).

Regarding safety benefits of in-person licensing requirements, our study results show no significant association between in-person renewal and crash hospitalization rates among any age group based on the models specified. Others have reported significant association between in-person renewal and lower fatal crash rates among drivers ages 85 and older (RR 0.83, 95% CI

0.72; 0.96), however their study compares fatal crashes, rather than crash-related hospitalizations.

This study is the first study, to our knowledge, that examines the role of mandated and legally protected physician reporting of at-risk older drivers on older driver crash hospitalizations. As in some states physicians are legally obligated to report to motor vehicle authorities drivers with conditions that impair their driving, it was hypothesized that crash hospitalization rates in states with such restrictions would be lower. Across all age groups and the various model specifications, legally mandated physician reporting as well as legally protected physician reporting failed to show any statistical significant relationship to older driver crash hospitalizations. This is surprising as a review of studies by Brown et al., (2004) highlights three studies demonstrating the importance of physician recommendations on driving cessation among older adults (Brown & Ott, 2004). As noted by Brown, a study by Drickamer et al. (1993) showed that the overwhelming majority of surveyed physicians discuss driving with their patients (Drickamer & Marottoli, 1993). A separate study by Persson (1993) showed that a quarter of interviewed older drivers had stopped driving based on the advice of their physician (Persson, 1993). Furthermore, a study on driving privilege outcomes among older drivers reported to the Oregon department of motor vehicles showed that only 10% of those reported to the Oregon DMV regained driving privileges following testing or hearing (K. M. Snyder & Ganzini, 2009). Based on these understandings, mandated physician reporting states were expected to have lower crash hospitalization rates. On the other hand, two Canadian studies examining mandatory cardiac illness reporting and a separate study examining epilepsy reporting, found that such mandatory physician reporting had a negligible impact on crashes (McLachlan, et al., 2007; Simpson et al., 2000b). Some factors that may explain this lack of association include that physicians may be unaware of reporting requirements in their state or may attempt to avoid harming their rapport with their patient (Eby & Molnar, 2010). Others have argued that physicians may be not sufficiently trained in identifying at-risk drivers, especially through routine medical visits, for reporting purposes (Aschkenasy, Drescher, & Ratzan, 2006a).

With regard to results for road-testing, study results show no consistent effect of road-testing on crash hospitalization rates. These results may be due to the low number of states with road testing requirements (2) making estimates unreliable, even though other studies have shown that mandatory assessment that may include road testing was not associated with crash rates in Australia (Langford, et al., 2004).

This study has a number of limitations. One drawback of this study is that for a number of licensing requirements, notably on-road testing; only limited numbers of observations were available due to the low number of states with such requirements, making comparisons more difficult. A separate limitation, that is inherent in many transportation related examinations and highlighted elsewhere, is the difficulty in controlling for state-specific confounding factors not immediately identified. Another limitation is the lack of documentation on driver fault among those hospitalized due to crashes. If there are significant differences in older driver fault in crash causation between states, our estimates may be biased. This is based on the assumption that licensing and reporting requirements are targeted towards those drivers most likely to be at fault in crashes; hence the best comparisons would be based on driver fault rather than among all hospitalized drivers. A separate limitation is due to potential differences in crash severity between crashes in the various states. Although this study attempts to address state-based trends by including crash-rates of those 55-59, not directly targeted for licensing restrictions, some state differences may yet impact hospitalization rates. One such difference is potential differences in crash outcomes between states, whereby different proportions of those that crash appear in hospitalization data, hence influencing the resulting populations compared.

In conclusion, across the 3 modeling approaches, vision testing at in-person renewal was related to significantly lower crash hospitalizations among driver's ages 60 to 74 with other state licensing laws such as in-person renewal and road testing indicated inconsistent and borderline association with crash hospitalization rates among select groups. Interestingly, physician reporting mandates, mandated or legally protected, and length of licensing renewal lacked any independent association with crash hospitalizations.

5.0 DEMENTIA AMONG OLDER DRIVERS IN MVC HOSPITALIZATIONS BY STATE DRIVER LICENSING AND PHYSICIAN REPORTING LAWS

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5.1 ABSTRACT

Objective: To determine the effect of state licensing and physician reporting requirements on motor vehicle crash hospitalizations among drivers with a diagnosis of dementia. This examination is guided by the hypothesis that states with stricter licensing restrictions and mandatory physician reporting would result in a lower proportion of hospitalized drivers with a diagnosis of dementia than states without such requirements.

Methods: Motor vehicle crash-related hospitalized drivers 60 and older with a diagnosis of dementia (n=5,564; 53.6% male) and hospitalized drivers 60 and older without a dementia diagnosis (n=131,423; 62.4% male) were identified from the States Inpatient Databases (SID) for years 2004 to 2009. Among hospitalized drivers, proportions of hospitalized older drivers with a diagnosis of dementia were estimated using two binomial regression models (logistic regression) to examine the effect of state licensing law provisions, including in-person renewal, vision testing, road testing and length of renewal cycle, and risky driver physician reporting laws on dementia prevalence. Models adjust for person-level covariates that include driver gender, urban/rural crash location and state-level covariates that include number of licensed drivers per age group, state primary seat-belt enforcement laws, state unemployment rate, annual state total precipitation, state per capita fuel consumption, access to trauma centers and urban speed limits.

Results: In-person renewal was significantly associated with a significantly lower proportion of dementia among hospitalized drivers among drivers ages 60 to 69, adjusted OR (0.62. 95% CI 0.47; 0.83). Similarly, vision testing at renewal showed significant association with a lower prevalence of dementia among hospitalized older drivers among drivers ages 60 to 69, adjusted odds ratios OR 0.72 (95% CI 0.54; 0.94). Among the oldest old, hospitalized drivers ages 80 and older, road testing was the only licensing requirement that was significantly related to a lower prevalence of

dementia among those hospitalized due to motor vehicle crashes, adjusted OR 0.68 (95% CI 0.53; 0.88). Mandated physician reporting indicated lower proportions of dementia among those hospitalized for driers 60 to 69, however it was not independently associated with a statistically significant decrease, adjusted OR 0.78 (95% CI 0.45; 1.36). Legally protected physician reporting or other licensing requirements showed no association with dementia among hospitalized adults.

Conclusions: Vision testing at in-person renewal and in-person renewal requirements was significantly related to a lower prevalence of dementia among hospitalized older adults among drivers ages 60 to 69. Road testing was significantly associated with a lower proportion of dementia among hospitalized drivers ages 80 and older. Other state licensing laws or physician driver reporting laws lacked any independent association with prevalence of dementia among hospitalized drivers.

5.2 INTRODUCTION

In 2009, some 175,000 adults 65 and older were admitted to emergency departments due to MV related injuries, with another 31,000 further transferred or hospitalized (CDC, 2011). In that same year 4,396 adults 65 and older were killed as drivers of a motor vehicle in-transport (NHTSA, 2011). Since 2001 some 1.4 million older adults have received emergency department (ED) treatment (CDC, 2010) and over 64,000 have died due to motor vehicle (MV) injuries (NHTSA, 2009) and motor-vehicle related hospitalizations and injuries for 2008 alone have resulted in an estimated $3 Billion in direct medical cost (Corso, et al., 2006; Naumann, et al., 2010)

Some argue that after teenage males, older adults have the highest per capita MV fatality rate (Morrisey & Grabowski, 2005; NHTSA, 1999) making it the second leading cause of injury death after falls (CDC, 2010). Others show that MV-related injuries result in significant post-crash disability, accounting for 25% of limitations in activities of daily living (ADL) among those with injury-related chronic disabilities (Guerrero JL, 1999). And by 2050 there will be some 88.5 million older adults, representing 25% of the driving population, an increase from the current 16.1% of the driving population (US Census, 2009). Following current trends it is expected that more than 80% of older adults will be licensed to drive.

Additionally while studies show that age-related declines in vision and cognitive functioning as well as physical changes may affect some older adults' driving performance (Owsley, 1999), age is only mildly correlated with driving performance in models that adjust for co-morbid conditions (Grabowski, et al., 2004a). Others have demonstrated that only older drivers that drive fewer than 1900 annual miles (3000 km) are at increased risk of crash

(Langford, et al., 2006) or have shown that increased fatality rates among older drivers may be due their inherent fragility (Li, et al., 2003).

While older people are highly dependent on personal vehicle as a means of transportation (Collia, et al., 2003) older drivers are also at greater risk of experiencing decreased physical and cognitive performance needed to drive safely (Edwards, et al., 2009; Owsley & Ball, 1993; Owsley & McGwin, 1999; Zhang, et al., 2007). These functional capabilities include visual abilities needed to detect hazards (Owsley, 1994), perceptual skills needed to accurately judge traffic gaps and patterns (Zhang, et al., 2007), as well as cognitive functions required to make rapid and appropriate maneuvering decisions (Duchek, et al., 1998). Highlighting at-risk groups, in addition to general age-related changes in performance, some point to drivers with Alzheimer's disease (AD) who experience higher number of accidents and performed worse on road tests than those without the condition, and experience more rapid declines in driving performance than study controls (Ott, et al., 2008). Others further note that older drivers with mild to severe AD differed significantly from study controls in driving exam performance and were deemed as unsafe drivers (Hunt, et al., 1993). However, some yet highlight that the driving performance of drivers with probable AD (Clinical Dementia Rating < 0.5) was within the levels tolerated for other driving groups; hence such condition provides no ground for driving restrictions (Dubinsky, et al., 2000).

Nevertheless, state governments, to the dismay of many older drivers, have introduced different methods for ensuring the safety of the driving public, including that of the older driver. A number of states now mandate physician reporting of patients with driving-related medical conditions and have introduced stringent age-based licensing screening criteria that require in-person renewals, vision tests, physician reports, written and road tests as well as a shorter license renewal period. The purpose of this study is to examine the role of state driver licensing laws and physician reporting requirements on the characteristics of crash hospitalized older adults, principally with regard to medically diagnosed dementia among drivers. Findings will contribute to the safety and wellbeing of older adults by determining appropriate licensure policies, the optimal role of physicians in licensing.

5.3 METHODS

5.3.1 Study population

This study uses hospital admission data of older adult drivers from US Hospitals, from 2004 to 2009. This information is made available through the State Inpatient Databases (SIDs) of the Agency for Healthcare Quality and Research (AHRQ) Healthcare Cost and Utilization Project (HCUP), a public-private partnership. Details on how the SID data are collected can be found on the AHRQ website (Agency for Healthcare Research and Quality, 2008). Adult drivers hospitalized due to motor-vehicle crashes were identified based on discharge abstract ICD-9-CM External Causes of Injury Codes (E-codes) E810-E819 with a fourth digit of .0 (driver) in any of the first four E-code fields.

The SIDs contains patient information from standardized discharge abstracts that include demographic and clinical data at the patient level and information at the hospital level. Over the 6 years of data available for the study, a total of 136,987 drivers 55 and older, hospitalized due to motor-vehicle crashes, were identified. In line with other hospital based studies, to avoid double counting, hospitalized adults were dropped if their incoming source was another hospital or long-term care center. Among these 136,987 hospitalized older drivers, 5,911 drivers with a diagnosis of dementia were also identified. Dementia was identified based on ICD-9-CM codes (294.8, .9, 298.9, 046,.0 -.3, 094, .1, 290.0, .1, .10 -.13, .20, .2-.4, .40 - .43, .8, .9, 2902.1, 437.0, 291, .1, .2, 292.82, 294.0, 294, 294.1, 345.0, 310, 310.1, 310.8-.9, 331,.0,- .9, .82, .89, 332,.0, 333.4, 437, .0, 797) in any of the first 10 patient diagnosis fields.

Since state hospitalization data sharing is voluntary, not all state hospitalization data were available for the whole period covered. There were 37 states reporting in 2004 and 2005, 39 in 2006, 40 in 2007, 32 in 2008 and 44 in 2009, resulting in 229 state-year observations.

5.3.2 Study variables

Information on the state requirements for mandatory physician reporting of at-risk drivers and legal protection of reporting physicians was obtained from Physician's Guide to Assessing and Counseling Older Drivers, 1st and 2nd editions, published in 2004 and 2010 by the American Medical Association (AMA) and the National Highway Traffic Safety Administration (NHTSA), state DMV's, the AAA Foundation's License Policy and Practices Database (AAA, 2011). Data on older driver state licensing requirements were obtained from the AAA Foundation's License Policy and Practices Database (AAA, 2011), the Insurance Institute for Highway Safety (IIHS) older drivers, licensing renewal provisions (IIHS, 2011b), state DMV's, and the AMA/NHTSA guides (AMA, 2004, 2010).

Data on adjusting variables were collected from a number of sources. Seatbelt requirements were obtained from the IIHS belt-use laws depository (IIHS, 2011d). Urban and rural speed limits were also obtained from the IIHS (IIHS, 2011c). Data on annual total state precipitation was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NOAA, 2011) whereas data on annual state motor-fuel consumption was obtained from the US Federal Highway Administration's annual Highway Statistics publications 2004-2009 (FHWA, 2011). Data on trauma center access reflects access to Trauma I and II centers within 45 minutes as collected in 2005 by Branas and colleagues (Branas, et al., 2005). Data on annual state unemployment rates were obtained from the US

Department of Labor's Bureau of Labor Statistics (BLS)(BLS, 2011). The University of Pittsburgh Institutional Review Board classifies this study as exempt. All analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, North Carolina).

5.3.3 Parameterization of variables

Hospitalized drivers due to motor-vehicle crash were identified from state hospitalization databases, with drivers grouped into 3 age cohorts (60-69, 70-79 and ages 80 and older). Given the changes in state requirements at varying intervals, it is argued that smaller age-groups would achieve a more accurate representation of the various driving requirements, however due to the low number of identified hospitalized drivers with a diagnosis of dementia; somewhat larger age groups were used.

Since mandated physician reporting of a broad category of at-risk drivers may substantially influence the driving population of a state and subsequently the crash-related hospitalizations of drivers in that state, a variable indicating this state characteristic was created. A binary variable denoting whether a state requires physician reporting was created, with 3 states participating in HCUP mandating physician reporting of at-risk drivers that go beyond those with conditions such as epilepsy or those characterized by loss of consciousness. Therefore only states with broad definitions of at-risk drivers that mandated physician reporting were categorized as such. A second binary variable was created to denote whether a state provided legal protection, such as immunity, to reporting physician, regardless if reporting was required by law. Among HCUP participating states, 27 states provided such protection.

Variables indicating state licensing requirements thought to influence driver safety were also generated for each age group to best reflect the licensing requirements for that age cohort.

One such requirement is that drivers present in-person for license renewal at least once within two or three renewal cycles, rather than using other renewal modes such as mail, phone or the web. This is thought to allow DMV personnel to assess driver's driving fitness. A binary variable indicating whether such requirement was in place was generated. Only 5 states did not require in-person renewals. Other licensing requirements applied include road test at licensing renewal and vision testing. From participating states, only two states required a road test for license renewal. Among analyzed States, 36 states required vision acuity testing as a precondition to continued driving, when presenting in-person for license renewal. Furthermore, state license renewal periods, measured in years, was also included in the model. Renewal period indicating the license validity length, varied considerably among those 60 to 70, with less variability among the older age groups.

In addition to state physician reporting requirements and licensing requirements, eight other variables related to older driver safety were generated to be included as adjusting variables. The state's seat-belt enforcement requirements were reflected in a binary variable indicating whether a state practices primary seat-belt enforcement, whereby being unbelted is sufficient reason for police enforcement. Another element that may influence the likelihood of crash-related hospitalization is state's weather conditions. States annual total precipitation was used to represent this element in the model. A continuous variable reflecting precipitation was computed. Adverse weather conditions, especially rain, are considered road hazards for many drivers, and older drivers are known to avoid driving during inclement weather, hence the need to adjust for this factor given its variation across the United States (Kostyniuk & Molnar, 2008; Okonkwo, et al., 2008). A binary variable reflecting the speed limits in state's urban areas was included as well, indicating whether the speed limit in urban roads was equal or higher than 60 mph.

An indicator variable for patient's gender, rural or urban location was computed, and included in the analyses as a control variable. We also created a variable to indicate states region, as to control for any region-wide characteristics in hospitalizations and crashes. States were separated into four regions (West, Midwest, Northeast and South) based on US Census Bureau Regional divisions (Census, 2009). To adjust for differences in emergency care access between states among older adults involved in crashes, a variable denoting access to trauma centers was included. This variable indicates the proportion of the state's population that has access to Trauma I and II centers within 45 minutes of their residence as collected in 2005 (Branas, et al., 2005). Furthermore, to adjust for any state differences in road infrastructure, safety features of on-road vehicle fleet and other factors (Evans, 1991; Ruhm, 1996), a variable indicating annual real state Gross State Product (GSP) per capita income was included. To further adjust for any differences in driving exposure, a variable indicating states annual fuel consumption per capita was entered in the model (FHWA, 2004-2009).

5.3.4 Statistical analyses

The person-level model uses logistic regression to examine the role of licensing and physician reporting requirements on the prevalence of dementia among hospitalized older drivers. The total number of hospitalized drivers per age group is used as the denominator on which the probability of hospitalized drivers having a diagnosis of dementia is based. In addition to gender, patient urban or rural location, diagnosis of dementia, race was considered as an additional person-level control variable, however due to the large number of missing values (>25%), this variable was dropped from consideration.

In addition to examining the role of identified predictors on hospitalization rates of adult drivers, separate models were specified examining their role on the number of drivers with a diagnosis of dementia among hospitalized drivers. The role of mandated physician reporting requirements is of special interest in this examination, given the hypothesis that states that mandate physician reporting are expected to have a healthier driving population and thus a lower representation of drivers with dementia, as a proxy measure, among the crash-related hospitalized drivers. The Hosmer and Lemeshow goodness of fit test is used to assess accurate specification (Hosmer, 2000).

All models computed use Generalized Estimating Equations (GEE), an adjustment method developed by Liang and Zeger (1986) and used by SAS, to apply generalized linear models (GLM) to our data, treated as repeated measures data (Zeger & Liang, 1986) . In order to account for the non-independence of observations, GEE applies an additional term, indicating correlation between observations at the cluster specified, to the model. In our case this term is computed using an autoregressive correlation structure, a structure which in our case argues that hospitalizations that occur closer in time have a higher correlation than those with larger time intervals. While GEE based estimates are robust to potential correlation structure misspecification, the auto-regressive structure of correlation of within-cluster observations is most appropriate for our data as they contain a time order component (Hosmer, 2000; Pan, 2001) This approach produces the most conservative standard error estimates and is appropriate given the changing driving environment.

5.3.5 Model specifications

To address the role of licensing and medical reporting requirements on dementia prevalence among hospitalized older drivers, two logistic regression models were specified. **Model 1 (M1):** The first model specification examines the proportion of hospitalized older drivers with a diagnosis of dementia among three age cohorts (60 to 69, 70 to 79 and ages 80 and older) using multivariate logistic regression. The outcome measure is the proportion of hospitalized older adults with a diagnosis of dementia among hospitalized older drivers per age-group specified, with the set of independent variables including mandatory physician reporting, legally protected physician reporting, at least one in-person renewal within 3 renewal cycles, states' vision testing requirements and licensing renewal period. A number of adjusting variables such as patient's gender, patient's urban or rural location, state's primary seat-belt enforcement requirements, annual precipitation, fuel consumption, unemployment rate, proportion of state's population with 45 minute access to trauma 1 and 2 centers and variable indicating state's urban speed limit over 60 mph. Road testing was only included for models with ages 75 and older. An additional term adjusting for state regional differences based on US Census grouping was also added in the model. This model uses Huber-White adjusted standard errors for confidence interval estimation. **Model 2 (M2):** The second model specification uses the model 1 grouping and applies a GEE autoregressive first order correlation structure at the state level to compute standard errors for estimate confidence intervals.

5.4 RESULTS

5.4.1 Results

Table 15 shows the hospitalization and demographic differences between hospitalized older drivers with a diagnosis of dementia and those without such diagnosis. Given the higher prevalence of dementia among older adults, most dementia cases (47.8 %) were among hospitalized drivers ages 80 and older. Injury characteristics of drivers were also significantly different by dementia diagnosis. For example, while other fractures (fractures of vertebral column, pelvis, rib or other factures) accounted for 23% of primary diagnoses for those without dementia, these fractures only accounted for 16.6% for those with a diagnosis of dementia. Crushing or internal injuries were also significantly more prevalent among those without dementia than those with the condition (10.5% vs. 5.3%). On the other hand, intracranial injuries were significantly more prevalent among drivers with dementia than those without the condition (18.5% vs. 14.5%) p<0.001. Furthermore, while number of diagnoses was significantly higher among those with dementia than without the condition (9.6% vs. 8.6%), those without dementia had higher hospitalization charges ($51,596 vs. $38,969).

Table 15: Hospitalization differences according to dementia diagnosis

	Dementia Diagnosis			
	No		Yes	
	No.	%	No.	%
Age Group*				
60-69	54,992	41.8	957	17.2
70-79	43,908	33.4	1,946	34.9
80+	32,523	24.7	2,661	47.8

Table 15: Continued

Principal diagnoses*				
Fracture of lower limb	13,923	10.6	317	5.7
Other fractures	30,558	23.2	925	16.6
Intracranial injury	19,070	14.5	1,031	18.5
Crushing injury or internal injury	13,807	10.5	293	5.3
Fracture of upper limb	7,179	5.5	180	3.2
Superficial injury; contusion	7,202	5.5	248	4.5
Length of Stay (Mean Days)^	6.23		6.21	
Total Charges (Mean USD)^	$51,596		$38,969	
Number of diagnoses (Mean)^	8.66		9.59	

Chi-square test *p<0.001; T-test ^p<0.001

Hospitalization comparisons according to licensing and physician reporting and dementia diagnosis are presented in Table 16. The proportion of MVC-related hospitalized adults with a diagnosis of dementia was lower in states with mandatory physician reporting than those without such a requirement (11.6% vs. 13.6%; p<0.001). There was no significant difference in the proportion of drivers with dementia among hospitalized drivers according to any other licensing or reporting provision. Driver gender and whether hospitalized driver died in-hospital were two other hospitalization characteristics that were significantly different between the groups. Among hospitalized drivers with a diagnosis of dementia, 62.4% were male drivers, this in contrast to 46.4 among those without such diagnosis (p<0.001). Additionally, 3.4% of those with a dementia diagnosis died, in contrast to 4.6% among those without such a condition (p<0.001).

Table 16: Dementia among hospitalized drivers

		Dementia Diagnosis			
		No		Yes	
		No.	%	No.	%
Mandatory physician reporting*					
	No	113,522	86.4	4,918	88.4
	Yes	17,901	13.6	646	11.6
Physician reporting (LP)					
	No	44,260	33.7	1,892	34.0
	Yes	87,163	66.3	3,672	66.0
In-person renewal					
	No	16,903	12.9	689	12.4
	Yes	114,520	87.1	4,875	87.6
Vision testing at renewal					
	No	19,367	14.7	788	14.2
	Yes	112,056	85.3	4,776	85.8
Driver gender*					
	Male	70,404	53.6	3,470	62.4
	Female	60,994	46.4	2,094	37.6
Road Testing					
	No	126,964	96.6	5,395	97.0
	Yes	4,459	3.4	169	3.0
Died*					
	No	125,347	95.4	5,369	96.6
	Yes	5,997	4.6	188	3.4

Chi-square test *p<0.001; LP stands for "legal protection"

5.4.2 Model results

Table 17 presents the results of two model specifications examining the role of licensing and requirements on prevalence of dementia among MVC-related hospitalized drivers. While model results suggest that states with mandatory physician reporting have lower proportion of hospitalized drivers with a dementia diagnosis, these results are not statistically significant in any model specification. Similarly, legally protected physician reporting showed no significantly association with the prevalence of dementia among hospitalized drivers. In-person renewal and vision testing when renewing in-person showed significant association with a lower proportion of dementia among states with such requirements for drivers ages 60 to 69. Among this age group, states with in-person renewal had an odds ratio (OR) 0.62 (95% CI 0.47; 0.83) when adjusting for hospitalized driver's gender, urban location, seat-belt enforcement law, state unemployment rate, annual state precipitation, state per-capita fuel consumption, access to trauma centers, urban speed limits and regional differences. Vision testing was associated with a lower prevalence of drivers with a dementia diagnosis among this age group, OR 0.77 (95% CI; 0.54; 0.94) and showed no significant association with dementia prevalence among hospitalized drivers in any other age group. Road test requirements showed a significant association with a lower prevalence of dementia among hospitalized drivers only among drivers ages 80 and older, yielding an OR 0.68 (95% CI 0.53; 0.88) on GEE based models. On the other hand, renewal period showed no relationship with a diagnosis of dementia among hospitalized drivers among any examined age groups, in models using robust standard errors or GEE based empirical standard errors for confidence interval estimation.

Table 17: Logistic regression models – Dementia among hospitalized older drivers

		Mandatory physician reporting	Physician reporting (Protected)	In-person renewal	Vision testing when in-person	Road test	Renewal period
60-69	States without Law	860	339	126	126		NA
	States with Law	97	618	831	815		
	Adjusted OR (95% CI) M1	0.79 (0.59; 1.06)	0.99 (0.84; 1.17)	0.63 (0.49; 0.80)^	0.77 (0.61; 0.97)*		1.01 (0.95; 1.08)
	Adjusted OR (95% CI) M2	0.78 (0.45; 1.36)	1.05 (0.91; 1.21)	0.62 (0.47; 0.83)^	0.72 (0.54; 0.94)*		0.97 (0.9; 1.04)
70-79	States without Law	1,733	680	233	268	875	NA
	States with Law	213	1,266	1,713	1,678	66	
	Adjusted OR (95% CI) M1	0.95 (0.77; 1.17)	0.97 (0.87; 1.09)	1.00 (0.84; 1.19)	1.13 (0.96; 1.33)	0.84 (0.62; 1.13)	0.98 (0.93; 1.02)
	Adjusted OR (95% CI) M2	0.87 (0.53; 1.42)	1.01 (0.82; 1.25)	0.88 (0.59; 1.3)	0.98 (0.73; 1.32)	1.08 (0.73; 1.59)	0.93 (0.84; 1.03)
80+	States without Law	2,325	894	330	378	2,585	NA
	States with Law	336	1,767	2,331	2,283	76	
	Adjusted OR (95% CI) M1	1.02 (0.87; 1.20)	0.99 (0.90; 1.09)	0.89 (0.77; 1.04)	1.02 (0.89; 1.17)	0.68 (0.52; 0.91)^	0.98 (0.95; 1.02)
	Adjusted OR (95% CI) M2	0.97 (0.82; 1.15)	0.99 (0.90; 1.08)	0.92 (0.79; 1.08)	0.97 (0.84; 1.11)	0.68 (0.53; 0.88)^	0.98 (0.95; 1.01)

*p<0.05; **p<0.10, ^p<0.01

M1- Adjusted for drivers' gender and urban/rural location, state primary seat-belt enforcement law, state unemployment rate, annual state total precipitation, state per capita fuel consumption, access to trauma centers, urban speed limits and regional differences. The dependent variable is the number of MVC hospitalized drivers with a diagnosis of dementia per specified age-cohort. Robust confidence intervals were estimated using Huber-White adjusted standard errors.

M2 - Confidence intervals were estimated based on a GEE autoregressive first order correlation structure at the state level based and results reported are based on empirical standard error estimates.

5.5 DISCUSSION

This study highlights the role of state licensing requirements and physician reporting laws on crash hospitalizations among drivers with dementia. This is the first study, to our knowledge, that examines the role of licensing and physician reporting requirements among drivers with a diagnosis of dementia hospitalized due to motor vehicle crashes. This comprehensive examination of older driver fatal crash involvement among states with different licensing requirement is based on the assumption that regression models used are appropriately specified without omissions of other covariates or confounding elements. The models specifications used aim to adjust for state and person-level factors thought to influence crash rates and indirectly hospitalization rates, such as primary seat-belt enforcement, speed limit and factors that may influence hospitalizations directly, such as access to trauma care. This study also attempts to adjust for the lack of independence among hospitalized drivers in their respective state cluster, due to within-cluster correlation, by obtaining GEE based regression estimates for model analyses. Similar approaches have been published previously with teen drivers (Grabowski, et al., 2004a; Grabowski & Morrisey, 2001; Houston, 2007; Masten, et al., 2011). It is of importance to note the relative consistency of results across the two model specifications, both when using Huber-White based robust confidence intervals and when using GEE based 1st order autoregressive correlation.

Model specifications, those controlling for state covariates and regional differences pointed towards three primary results. The first primary result is the significant lower proportion of hospitalized older drivers with dementia in states with in-person renewal requirements among drivers ages 60 to 69 (OR 0.63, 95% CI 0.49; 0.80). The second major result is the lower prevalence of dementia among driver's ages 60 to 69 in states with vision testing at in-person renewal (OR 0.72; 95% CI 0.54; 0.94). The third major result is the significant lower prevalence of dementia among hospitalized drivers ages 80 and older in states with mandatory on-road testing (OR 0.68, 95% CI 0.53; 0.88).

The significant association between visions testing at in-person renewals with lower odds of dementia among hospitalized drivers ages 60 to 69 lacks an immediate mechanistic explanation. While dementia is known to be associated with declines in attention performance, especially switching between visual targets for selective attention, it is unclear if such declines are the reason for the role of vision testing on lower hospitalizations among those with dementia (Parasuraman & Nestor, 1991). Some argue that elements of vision performance, such as visual field deficiencies, are not related to driving performance (Dow, 2011) and that the predictive value of commonly used vision tests for licensing are inconclusive as vision test scores do not adequately explain unsafe driving performance (Bohensky, et al., 2008) and thus there is little clarity on the mechanism of vision screening on crash hospitalizations among those with dementia. However, among the general driving population, vision screening has been found to be related to lower fatal crash rates, even if significant effects of vision testing were found primarily with drivers ages 70 and older, rather than those ages 60 to 69 as noted in our results (Levy, et al., 1995; McGwin, et al., 2008). One interpretation of this age-group difference may lay with the significant differences between drivers with dementia and those without a dementia diagnosis. We note that among hospitalized drivers with dementia, 47% were ages 80 and older, in contrast to 24% for others hospitalized due to motor vehicle crashes. Additionally, drivers with dementia were more likely to be male and have less life-threatening injuries. These differences may be a result of different population characteristics, even when matched according to age. This rationale is further supported by the result on the impact of in-person licensing renewal on dementia prevalence. As with vision testing, in-person renewal was shown to be related to a lower prevalence of dementia among drivers ages 60 to 69 in states with this requirement (OR 0.62, 95% CI 0.47; 0.83). As with vision testing, other studies point to the safety benefit of in-person renewal requirement among the oldest old of drivers (Grabowski, et al., 2004a). For example, Grabowski et al. (2004) reports lower fatal crash rates among drivers 85 and older in states with in-person renewal requirements (RR 0.83, 95% CI 0.72; 0.96). One possible explanation is provided by Kulikov (2011) who showed that licensing regulations such as vision testing and in-person renewal were major reasons for older driver's decision to reduce or stop driving (Kulikov, 2011b). Berger (2000) argued that as drivers with dementia may not comprehend their condition and its impact on driving, the responsibility for driving cessation falls on others. Through this, driving cessation among those with dementia, in states with in-person renewal requirements and vision testing when renewing in-person, may be significantly higher than among those without the condition, hence resulting in differences in dementia proportions among hospitalized drivers.

With regard to road-testing, our study results point towards significantly reduced odds of dementia among hospitalized drivers in states with road testing among drivers ages 80 and older (OR 0.68, 95% CI 0.52; 0.91). While studies on the role of road-testing on older driver crashes have found no impact on older driver crashes (Grabowski, Campbell, & Morrisey, 2004b; Morrisey & Grabowski, 2005), it is important to note that drivers with dementia perform significantly worse on on-road testing than those without dementia (Berndt, et al., 2008; Duchek, et al., 2003; Stav, Justiss, McCarthy, Mann, & Lanford, 2008), hence the impact of road testing may be different among this population.

This study is the first study, to our knowledge, that also examines the role of mandated and legally protected physician reporting of at-risk older drivers on dementia among hospitalized older drivers. As in some states physicians are legally obligated to report to motor vehicle authorities drivers with conditions that impair their driving, it was hypothesized that the proportion of hospitalized drivers with dementia in states with such laws would be lower than in states without such restrictions. Across all age groups, legally mandated physician reporting as well as legally protected physician reporting lacked any statistical significant relationship to prevalence of dementia among hospitalized older drivers. This is surprising as a review of studies by Brown et al., (2004) highlights three studies demonstrating the importance of physician recommendations on driving cessation among older adults (Brown & Ott, 2004). As noted by Brown, a study by Drickamer et al. (1993) showed that the overwhelming majority of surveyed physicians discuss driving with their patients (Drickamer & Marottoli, 1993). A separate study by Persson (1993) showed that a quarter of interviewed older drivers had stopped driving based on the advice of their physician (Persson, 1993). Furthermore, a study on driving privilege outcomes among older drivers reported to the Oregon department of motor vehicles showed that only 10% of those reported to the Oregon DMV regained driving privileges following testing or hearing (K. M. Snyder & Ganzini, 2009). Based on these understandings, mandated physician reporting states were expected to have lower proportions of hospitalized drivers with a diagnosis of dementia. Some factors that may explain this lack of association is that physicians may be unaware of reporting requirements in their state or may attempt to avoid harming their rapport with their patient (Eby & Molnar, 2010) or that physicians may have difficulties in identifying at-risk drivers (B. M. Dobbs, et al., 2002)

This study has a number of limitations. One drawback of this study is the relatively small sample size, which forced larger age grouping, thereby decreasing the accuracy of results, especially if significant heterogeneity exists within this grouping. Furthermore, although the examined period spans 6 years, for a number of licensing requirements, notably on-road testing, only limited numbers of observations were available due to the low number of states with such requirements, making comparisons more difficult. A third limitation, that is inherent in many transportation related examinations and highlighted elsewhere, is the difficulty in controlling for state-specific confounding factors not immediately identified.

In conclusion, across the modeling approaches, in-person renewal, vision testing at in-person renewal showed significant associations with lower dementia prevalence among hospitalized drivers ages 60 to 69. Road testing indicated significant association with lower dementia prevalence among hospitalized drivers ages 80 and older. Surprisingly, physician reporting laws, mandated or legally protected, and length of licensing renewal lacked any independent association with dementia among hospitalized older drivers.

6.0 SUMMARY OF FINDINGS

Three separate studies were performed to determine the effect of state licensing and physician reporting requirements on older driver safety. Studies were guided by the hypotheses that states with stricter licensing requirements and mandatory physician reporting would result in lower fatal crash rates, lower older driver crash hospitalization rates and a lower prevalence of dementia among those hospitalized compared to states with fewer requirements. The first study showed that vision testing when renewing in-person showed consistent association with lower fatal crash rates among four of the six age groups examined. Vision testing was especially predictive of a lower crash fatality rate among drivers ages 80 to 84 resulting in an (Incidence Rate Ratio [IRR], 0.81; 95% confidence interval [CI] 0.69; 0.96) when adjusting for person and state-level covariates, regional differences and driver 55 to 59 fatal crash rates. In-person renewal had borderline association with a lower crash rate among drivers 80 to 84. Surprisingly, road testing was associated with an elevated fatal crash rate in states with such a requirement for drivers 85 and older [IRR 1.43 (95% CI 1.2; 1.71)]. There was no significant association between state mandated physician reporting requirements, legally protected physician reporting requirements with fatal crash rates among groups examined. This study concluded that vision testing at in-person renewal was related to significantly lower fatal crash rates among four of the six age groups examined. Other state licensing laws such as in-person renewal and road testing indicated borderline association with fatal crash rates among select groups. Physician reporting, mandated or legally protected, and length of licensing renewal lacked any independent association with fatal crash rates.

In the second study we showed that vision testing at renewal showed significant association with a lower hospitalization rate for hospitalized drivers ages 65 to 74. For those ages 70 to 74, vision testing yielded an (IRR) of 0.76 (95% CI, 0.62; 0.93) when adjusting for other covariates. For drivers ages 75 to 84, vision testing was only significant in the first model specification, without adjusting for regional differences and crash rates of drivers' ages 55 to 59 in the respective states. Length of licensing renewal and road testing were not found to be related to a statistically different hospitalization rate in majority of the age groups examined, with the exception of a borderline ($p<0.10$) association for road testing with a lower hospitalization rate among drivers 75 to 79 when adjusting for covariates and regional differences (IRR 0.88, 95% CI 0.77; 1.01) and a similarly borderline lower crash hospitalization rate for states with longer licensing periods for drivers ages 70 to 74 (IRR 0.93, 94% CI 0.85; 1.01). There was no significant association between state mandated physician reporting requirements, legally protected physician reporting requirements with fatal crash rates among groups examined. Similarly in-person renewal was not independently association with lower crash hospitalization rates. This study concluded that vision testing at in-person renewal was related to significantly lower driver crash hospitalization rates among five of the six age groups examined in at least one modeling group. Other state licensing laws such as length of licensing renewal and road testing indicated borderline association with hospitalization rates among select groups. Physician reporting requirements, mandated or legally protected, and in-person renewal lacked any independent association with driver crash hospitalization rates.

The third study showed that in-person renewal was significantly associated with a significantly lower proportion of dementia among hospitalized drivers among drivers ages 60 to 69, adjusted OR (0.62. 95% CI 0.47; 0.83). Similarly, vision testing at renewal showed significant association with a lower prevalence of dementia among hospitalized older drivers among drivers ages 60 to 69, adjusted odds ratios OR 0.72 (95% CI 0.54; 0.94). Among the oldest old, hospitalized drivers ages 80 and older, road testing was the only licensing requirement that was significantly related to a lower prevalence of dementia among those hospitalized due to motor vehicle crashes, adjusted OR 0.68 (95% CI 0.53; 0.88). Mandated physician reporting indicated lower proportions of dementia among those hospitalized for driers 60 to 69, however it was not independently associated with a statistically significant decrease, adjusted OR 0.78 (95% CI 0.45; 1.36). Legally protected physician reporting or other licensing requirements showed no association with dementia among hospitalized adults. This study concluded that vision testing at in-person renewal and in-person renewal requirements was significantly related to a lower prevalence of dementia among hospitalized older adults among drivers ages 60 to 69. Road testing was significantly associated with a lower proportion of dementia among hospitalized drivers ages 80 and older. Other state licensing laws or physician driver reporting laws lacked any independent association with driver crash hospitalization rates.

Across all three studies, vision testing at in-person renewal was most consistently shown to have safety benefits by means of a lower crash rate, hospitalization rate and dementia prevalence among older drivers. Road testing was significantly associated with a lower proportion of dementia among hospitalized drivers ages 80 and older. Other state licensing laws such as in-person renewal and road testing indicated borderline safety benefits among select groups. Physician reporting mandates, mandated or legally protected, and length of licensing renewal lacked any independent association with fatal crash rates. However, it must be noted that apparent differences in the role of licensing and reporting requirements between studies may be due to the inherent differences in the groups studied, especially regarding results from the third study examining prevalence of dementia among crash-related hospitalized drivers.

7.0 PUBLIC HEALTH SIGNIFICANCE

Age-based driver licensing and physician reporting are controversial approaches to older driver safety. Additionally the scarcity of research, the conflicting conclusions and the significant mobility, injury and healthcare utilization implications underline the attention this problem merits. The European Transport Safety Council calls medical screening of older drivers as counterproductive and ageist (Morrisey, et al., 2006) and in the US, the District of Columbia specifically states that an applicant will not be required to retake the written or road test based solely on advanced age (IIHS, 2011) and some argue that introducing licensing and medical screening regulations for older drivers may be harmful to the driver rather than beneficial (Hakamies-Blomqvist, Johansson, & Lundberg, 1996). Furthermore, the introduction of barriers to driving in the form of added age-based licensing requirements is shown to reduce driving and facilitate driving cessation, even for those that may be fit to drive (Kulikov, 2011a).

Studies show that involuntary driving cessation may induce depression (Azad N, Byszewski A, Amos S, & FJ., 2005 ; Ragland, Satariano, & MacLeod, 2005; Siren, 2002) through a loss of independence (Fonda, Wallace, & Herzog, 2001), stressing the high value placed on mobility and independence by older adults. Although self-regulation, voluntary limitation of driving, is considered the best option for ensuring older driver safety, state licensure regulation and physician reporting requirements are quickly being put in place as mechanisms to identify at-risk drivers and remove their driving privileges. This study examined if age-based licensure policies or physician reporting requirements are indeed related to improved driver safety among older adults, as measured by fatal crashes, crash-related hospitalizations and prevalence of dementia among crash-related hospitalized drivers. Our results point toward the safety benefit of a select group of licensing requirements, namely vision testing and in-person renewal and road-testing for select ages, and highlights the lack of independent relationship between other licensing requirements and state physician reporting practices, whether mandated or voluntary, and older driver safety benefits. Our results provide some support and justification for the use of a limited group of licensing requirements, with select groups, and also support for those that argue that some restrictions may impair older driver mobility, harm their wellbeing with little safety benefit, namely physician reporting requirements, shorter licensing renewal periods and in-person renewal for a group of drivers.

A number of groups may find direct utility for these results. First, older drivers receive some clarification that more restrictions on driving do not translate in lower crash risk, which may inform their opinions on their rights and responsibilities with regard to lifetime driving. Second, families of older adults with driving related medical conditions, especially those with dementia, can use these results to inform their role in maintaining the safety and mobility of those with such conditions, especially given the lack of impact of physician reporting requirements on their safety. Third, physicians and physician groups and associations may find direction in these studies regarding their role in maintaining the safety and independence of their older patients. Furthermore, these results directly empower physicians to argue against mandatory reporting of their older patients under current processes, or demand training for adequately identifying at-risk older drivers, including new tools for doing so. Fourth, state licensing institutions and their respective Medical Advisory Boards would welcome these results to add to knowledge on the utility of older driver screening programs and other age-based licensing requirements on driver safety and adequately balance with driver's rights and privileges. Finally, this study's examination of the role of licensure policies on crash-related hospitalizations and prevalence of dementia among those hospitalized, also informs state and national health care policies regarding the utility of screening older patient drivers and demonstrates the need for improved physician tools for the assessment of older adult driving safety, especially given the lack of association between mandated physician reporting and a lower prevalence of dementia among those hospitalized.

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