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ABSTRACT

Objective: To estimate the association between past medical contacts and the risk of vehicle collision in a population of older drivers from the province of Quebec, Canada.

Design: Case-crossover study.

Setting: Quebec.

Participants: 111 699 older drivers involved in at least one vehicle collision between January 1988 and December 2000.

Main outcome measures: For each driver, the risk of having a vehicle collision while exposed and not exposed to a medical contact was compared. Separate conditional logistic regression analyses were conducted for all drivers and in four diagnostic-specific subgroups.

Results: We found a weak but statistically significant increased risk of all collisions associated with a medical contact within one month before the collision, for all drivers (OR=1.10, 95% CI 1.08 to 1.11), and for drivers with diabetes (OR=1.07, 95% CI 1.03 to 1.11).

Conclusion: Older drivers who have a collision are more likely to have been in contact with a physician in a short period before the collision. These findings suggest that there might be an opportunity to detect medical conditions that put older drivers at higher risk of collision, even if further research is needed to assess the potential effectiveness and practical modalities of screening.

INTRODUCTION

By 2030, one-fourth of the population in the member countries of the Organization for Economic Co-operation and Development will be aged 65 years and older (1). Ageing of populations in industrialized countries implies an increase of the proportion and number of older drivers. In the US, for instance, there were 19.9 million older drivers in 2002 and their police reported collision involvements are expected to increase by 178% by 2030 (2, 3). The proportion of licensed drivers aged 65 years and more is expected to increase from 12.6 in 2000 to 22.1% in 2030 in Australia, 12.6 to 20.0% in the US, 15.7 to 23.5% in the UK 16.1 to 25.8% in France, and 12.6 to 22.8% in Canada (1). In 2001, in the province of Quebec, there were almost one million people aged 65 and over (13.3% of the population) of whom 32.5% had a driving license (4, 5). In this province, there were 4 065 severe vehicle collisions, 13% involved older drivers which were also involved in 15% of lethal collisions.

Many studies assessed the relationships between age and the risk of collision. In 1995, Foley *et al* (6) showed that age was not significantly associated with the risk of collision, but many other studies supported that age was associated with being involved in a collision (3, 7-10). Even if age were clearly associated with the risk of collision involvement, the association is not strong enough to predict which drivers will actually be at higher risk of being involved in a collision. Nevertheless, the increase with age of the prevalence of medical conditions which may impair driving ability could logically put older drivers at higher risk of collision (11-13). Many studies showed that there is a high prevalence of cognitive impairment in older drivers involved in vehicle collisions; older drivers with dementia (Alzheimer's type) are also at higher risk of vehicle collision (14-16). Studies on driving resumption after a Traumatic Brain Injury (TBI) found that a subject who suffered from severe TBI has a significantly higher risk of being involved in a road traffic collision (17, 18). Many authors suggested that these patients should be assessed for both mental and physical status before resuming driving (17, 18).

Consequently, some countries, states or provinces have adopted standard or age-based license renewal procedures (19-21), and adoption of similar policies are debated in some countries in Europe (22). These procedures are often simple administrative renewal of the license; in other places applicants must perform tests such as vision tests or even road tests when specific medical conditions are present (19-21). In the US, in-person license renewal was related to a lower fatality rate among the oldest drivers, with a relative incidence rate decreased by 17% (23). However, other studies assessing mandatory evaluations targeting older drivers to prove their fitness to drive (23, 24) or education programs (25) did not demonstrate a reduction of collisions or an increased safety of older impaired drivers. Extension of similar interventions raises many issues. Beyond the validity of tests, one key question is the definition of the best opportunity to assess the ability to drive: early diagnostic among all drivers in the general population or at time of driver licence renewal (systematic screening), assessment during medical contacts for other reasons (case-finding), and what would be the role of health professionals in the detection and reporting process.

Assuming that any contact with a physician could be an opportunity to reach drivers with medical conditions associated with unsafe driving and thus detect drivers at risk of vehicle collisions, we performed a case-crossover study to estimate the association between a medical contact and the risk of road vehicle collisions in a population of older drivers from the province of Quebec, Canada.

METHODS

Participants

All older drivers (licensed drivers aged 65 years and older) from the province of Quebec, Canada, with a valid driving license and involved in a vehicle collision from 1988 to 2000 were eligible for this study. Eligible drivers were identified using the databases of the Universal Quebec Automobile Insurance Agency (SAAQ) and the medical file of the Quebec Health Insurance Agency (RAMQ). The SAAQ is responsible for driver's license registration and recording reports of motor vehicle collisions. Its databases, available from 1985 to 2000, contain information on the driver (socio demographic variables: age, sex) and allow to check the validity of the driver's license. They also contain information on the collisions (date, kind of road, environment conditions, severity, and number of victims involved…). We obtained medical data from the RAMQ, which is responsible for health care services for the province. These databases provide information on the practitioner (speciality, class, and establishment), on the act (code, date, and amount) and on the diagnosis (code). In all databases, drivers have a unique identifier and it was possible to cross information on both collisions and medical visits.

Design

The case-crossover design (26) is appropriate when a brief exposure (medical contact) is associated with an increase of the risk of an acute event (the collision). Each driver is his/her own control and thereby confounding due to fixed characteristics of the driver is eliminated.

Time of collision

Because the RAMQ databases were only available from 1988, only collisions after 1988 were considered for inclusion. The time of collision (index date) was defined as the date of the first collision that occurred between 1988 and 2000. To provide equal availability of control time periods to all subjects (see the definition of control periods below), the index date was to be preceded by a collision-free period of at least 12 months. In a first analysis, we considered all first collisions. As severe collisions are unlikely to be underreported (27), we also restricted a secondary analysis to

severe collisions, defined as lethal collisions and collisions resulting in a hospitalization for at least one person involved. We finally analysed severe collisions adding material damages greater than Canadian $500.

Hazard and control periods

We defined the risk period as the first one-month period preceding the index date. We used as control periods the four one-month periods preceding the risk period. We compared exposure to a medical contact during the risk period with exposure during control periods (fig 1).

fig. 1 around here

Assessment of exposure

For all periods, drivers who had been in contact, at least once, with a physician (thereafter called medical visit) were considered as exposed, whatever the diagnosis associated with the visit. Because the exact time of the visit is not reported in the databases, we excluded visits done the day of the collision, to identify only exposures that occurred strictly before the time of collision. Subgroups of drivers potentially at higher risk of unsafe driving (14-18, 28) were also defined, according to diagnostic codes of the International Classification of Diseases (ICD-9) as: 1) patients with diabetes (ICD code from 250.0 to 250.7, and from 250.9 to 251.1), 2) patients with dementia (ICD code 290.0, 290.2 to 290.4, 331.0, and 331.2); 3) patients with psychotic disorders (ICD code from 295.0 to 295.9, 297.1, 301.0, and 301.2), and 4) patients with consequences of TBI (ICD code 800.1, 800.3, 801.1, 801.3, 803.1, 803.3, 804.1, 804.3, 850.0, 851.0, 851.1, and 907.0).

Statistical analysis

We used a conditional logistic regression to estimate the risk of vehicle collision in drivers who have been in contact with a physician before the collision (29). We conducted separate analyses for: all collisions, severe collisions only, and severe collisions or material damages greater than Canadian $500. The adjusted odds ratios were estimated for all drivers, and for drivers in the four diagnostic-specific subgroups. As the numbers in the diagnostic-specific subgroups of dementia, psychotic disorders and consequences of brain injury were small in the group of severe collisions only (fig 2),

results are not presented in this paper. Finally, sensitivity analyses were carried out using different lengths and number of control periods. All the analyses were performed using the SAS® software version 9.

RESULTS

Study population

There were 434 389 collisions recorded by the SAAQ from January 1st 1985 to December 31st 2000 (fig 2). Almost 83% of drivers involved were men with a mean age of 66 years (7.5). Most collisions involved material damages greater than Canadian $500 (62.3%), 3% were considered as severe collisions, and less than one percent was lethal.

fig. 2 around here

We included in this analysis 111 699 vehicle collisions, including 3 318 severe collisions, recorded from 1988 to 2000 (table 1). These collisions were most often located in business areas and resulting in material damages greater than Canadian $500.The mean age of drivers involved was 71 years (0.5), and 80% were men. These 111 699 collisions resulted in 33 051 victims, 86.5% of whom were slightly injured. Characteristics of collisions and drivers were not different in the four diagnostic-specific subgroups, except in the group of drivers with dementia where the mean age was higher (74 years (5.8)). Detailed descriptive characteristics of drivers in diagnostic-specific subgroups are available upon request to the authors.

Table 1: Characteristics of vehicle collisions in which older drivers were involved in the province of Quebec, Canada (1988 – 2000)

Variables	All collisions (n=111 699)		Severe collisions only * (n= 3 318)		Severe collisions or material damages > Canadian $500 (n=74 941)	
	n	%	n	%	n	%
Collision severity						
Material damages (≤Canadian $500)	18 364	16.4	NA	NA	NA	NA
Material damages (>Canadian $500)	71 623	64.1	NA	NA	71 623	64.1
Injury without hospitalization	18 394	16.5	NA	NA	NA	NA
At least one hospitalized victim	2 802	2.5	2 802	2.5	2 802	2.5
Lethal	516	0.5	516	0.5	516	0.5

Victims involved						
All	33 051	100.0	6 618	100.0	6 618	100.0
Slightly injured	28 590	86.5	3 849	58.2	3 849	58.2
Seriously injured	3 849	11.6	2 157	32.6	2 157	32.6
Dead	612	1.9	612	9.2	612	9.2
Sex (men)	89 301	80.0	2 730	82.3	60 095	80.2
Age						
mean (SD)	71	5.0	72	5.3	71	5.0
median [interquartile interval]	70	[67-74]	71	[68-75]	70	[67-74]
At least one medical contact						
Risk period	60 556	54.2	1 780	53.6	40 341	53.8
Control periods	58 219	52.1	1 746	52.6	38 786	51.7

NA: not applicable

* Lethal collisions and collisions involving at least one hospitalized victim

Medical contacts

Fifty-four percent of all drivers had at least one medical contact during the month preceding the collision (against 52% during at least one control period). The frequency of medical contact in the risk period was higher in drivers with dementia (66%) and drivers with diabetes (60%). For drivers with diabetes, the frequency of medical contact in the control periods was the same as in the risk period (60%), whereas drivers with dementia were most often exposed during the control periods (71%). There was a weak but statistically significant increased risk of all collisions associated with a medical contact within one month before the collision, for all drivers and for drivers with diabetes (table 2). This weak and statistically significant association was also observed for severe collisions or material damages greater than Canadian $500, for all drivers and drivers with diabetes. In the group of severe collisions only and in the other diagnostic-specific subgroups, there was no significant association between the risk of collision and recent medical contacts.

Table 2: Adjusted risk of vehicle collision associated with a previous medical contact in older drivers from the province of Quebec, Canada (1988 – 2000)

	n	OR (95% CI)†	p
All collisions			
All drivers	111 699	1.10 (1.08 to 1.11)	$< 10^{-3}$
Drivers with diabetes	16 102	1.07 (1.03 to 1.11)	< 0.01
Driver with dementia	403	0.94 (0.73 to 1.21)	0.62
Drivers with psychotic disorders	392	1.13 (0.88 to 1.47)	0.33
Drivers with consequences of brain injury	81	1.31 (0.76 to 2.33)	0.33
Severe collisions only*			
All drivers	3 318	1.05 (0.97 to 1.13)	0.26
Drivers with diabetes	498	0.93 (0.75 to 1.15)	0.51
Severe collisions or material damages greater than Canadian $500			
All drivers	74 941	1.10 (1.08 to 1.12)	$< 10^{-3}$
Drivers with diabetes	10 663	1.07 (1.03 to 1.12)	< 0.01
Driver with dementia	234	1.02 (0.73 to 1.42)	0.92
Drivers with psychotic disorders	237	1.04 (0.75 to 1.44)	0.70
Drivers with consequences of brain injury	51	1.18 (0.60 to 2.34)	0.63

* Lethal collisions and collisions involving at least one hospitalized victim

† Odds-ratios (OR) with 95% confidence intervals determined by conditional logistic regression

Sensitivity analyses

Changing the length and number of study periods did not affect the results, except when using a risk period of two months matched with two control periods (table 3). With the increased power induced by this matching, a borderline statistically significant association was observed for all drivers in the group of severe collisions only (OR=1.10, 95% CI 1.01 to 1.20).

Table 3: Sensitivity analyses of the estimation of the risk of vehicle collisions associated with a previous medical contact in older drivers (all older drivers and drivers with diabetes) from the province of Quebec, Canada (1988 – 2000)

	Sample size*	Control periods		Total study period‡ (months)	Exposed in the risk period§ %	OR (95% CI)¶
		n	length†			
All collisions						
All drivers	111 699	1	2	4	75.6	1.10 (1.08 to 1.12)
	115 468	2	2	6	73.2	1.15 (1.13 to 1.17)
	111 699	4	1	5	54.2	1.10 (1.08 to 1.11)
	111 699	9	½	5	32.9	1.00 (0.99 to 1.02)
Drivers with diabetes	16 768	2	2	6	76.2	1.12 (1.07 to 1.17)
	16 102	4	1	5	60.2	1.07 (1.03 to 1.11)
Severe collisions only						
All drivers	3 429	2	2	6	72.3	1.10 (1.01 to 1.20)
	3 318	4	1	5	53.6	1.05 (0.97 to 1.13)
Drivers with diabetes	507	2	2	6	77.9	1.18 (0.90 to 1.56)
	498	4	1	5	57.8	0.93 (0.75 to 1.15)
Severe collisions or material damages > Canadian $500						
All drivers	77 490	2	2	6	72.8	1.15 (1.13 to 1.17)
	74 941	4	1	5	53.8	1.10 (1.08 to 1.12)
Drivers with diabetes	11 102	2	2	6	76.1	1.10 (1.05 to 1.15)
	10 663	4	1	5	60.5	1.07 (1.03 to 1.12)

* Sample size can vary in a same group because duration of the study depends on the length of observation period and number of control periods

† Length of each control period (months)

‡ Total study period = risk period + control periods

§ At least one medical contact during this period

¶ Odds-ratios (OR) with 95% confidence intervals determined by conditional logistic regression

DISCUSSION

We found evidence of a slightly increased risk of all vehicle collisions associated with a medical contact within one month before the collision, for all drivers and for drivers with diabetes. The same result was observed in the group of severe collisions or material damages greater than Canadian $500, but not in the group including severe collisions only. Thus, older drivers who have a collision, especially those with diabetes, are more likely to have been in contact with a physician in a short period before the collision.

Strengths and potential limitations of the study

The case-crossover design is efficient as it does not require a control group and, as each case is his/her own control, it neutralizes possible confounding effect due to long-lasting characteristics of the driver (26, 30). One limitation of this design is the assumption that exposure to potential confounding due to unstable factors other than the exposure of interest is the same in both risk and control periods. For instance, we implicitly assumed that drivers had the same driving patterns in both the risk and control periods. If study subjects did not drive during the control periods, they were obviously not at risk of being involved in a vehicle collision, resulting in a possible overestimation of the association between medical contacts and the risk of collision. However, we think more plausible that, if the risk of collision was to be related to an aggravation of a medical condition, older drivers could be more likely to decrease their driving just before the collision. Indeed, drivers often adopt self-regulation strategies whenever there are aware of their diminishing ability to drive (31, 32), therefore would be more likely to stop driving during the risk period, resulting in an underestimation of the association.

As we did not know the exact time of collision, we excluded drivers who have been in contact with a physician the day of the collision, to avoid a misclassification related to the inclusion of medical contacts that actually occurred after the collision. By doing so, we probably also have excluded drivers who had a medical contact just before the time of collision. The exclusion of these drivers, plausibly at higher risk of collision, could have lead to an underestimation of the association between relevant medical contacts and the risk of collision.

In a case-crossover design, the total hazard period is defined as a time interval, after a trigger, when the subjects experience an increased risk of the outcome (30). This hazard period may be divided into several periods of different degrees of excess risk. The risk period corresponds to the period when the incidence rate of the outcome is supposed to be increased. In our study, we assumed that the length of the risk period, in which a medical contact was hypothesized to be associated with a vehicle collision, was one month. The sensitivity analyses performed indicate that this length of the risk period used with four matched control periods was a satisfactory design in this population of older drivers from Quebec. However, beyond the impact on statistical significance, it is obvious that a medical evaluation repeated monthly to detect drivers with at-risk medical conditions, would not be possible in practice.

One reason some associations were not statistically significant is the lack of statistical power in three of the diagnostic-specific subgroups. Indeed, numbers in the subgroups of dementia, psychotic disorders and consequences of TBI were very small. Thus, a screening program targeted at a rare diagnostic-specific subgroup to prevent a rare event, like a collision, would have necessarily a weak impact.

Conclusion and implication for prevention

Our findings suggest that there might be an opportunity, during usual medical visits, to detect medical conditions that put older drivers at higher risk of collision. However, a medical contact defined as a medical visit is only an indirect indicator of the opportunity to detect high-risk older drivers. The actual detection would imply that the medical visit should include an evaluation of driving competencies, but, reliable, valid and applicable screening tools to predict the actual ability to drive remain to be developed. Published studies suggest that only on-road assessment tests are reliable and valid tools to determine driving competency (15, 33-37). These tests, however, are time-consuming, expensive (22), and not necessarily appropriate for older drivers because they are based on driving skills sometimes over learned by the older driver (35, 37). In the hypothesis that reliable and valid tests could be developed, other issues need to be resolved before a screening program could be implemented. Firstly, it is to decide whether the role of the physician would be based on a voluntary or mandatory reporting system; level of mandate could dramatically modify the participation of physicians. Secondly, once unsafe driving is detected, it is not obvious what would be the most effective intervention to reduce the risk of collision. Different kinds of interventions, more or less restrictive, have been suggested in the literature including educational or training programs, driving restrictions (geographic areas, time and day limitations), or complete driving cessation. Uncertainty on the effectiveness of these interventions is due to the negative effects potentially related to driving restrictions (35, 38). In the specific case of older drivers, potential negative consequences related to a reduction of driving could be an increase of dependency, isolation or depression (37, 39, 40). Ultimately, a screening program should be recommended only if positive effects outweigh negative effects. This uncertainty is a likely reason why recent studies recommend helping older drivers maintain ability to drive safely rather than simply remove the permission to drive (25). Whatever the kind of intervention and context of implementation, the ability to demonstrate that a medical contact is associated with an increased risk of collision, thus could represent an opportunity to detect drivers potentially at risk of collision, remains an important step for policy making.

Keys points

Although older drivers seem at higher risk of collision per mile driven, many authors suggest that, instead of age itself, it is rather the increase with age of medical conditions which may impair driving, that could put older drivers at higher risk of collision.

Recent medical contacts (within one month before the collision) were significantly associated with an increased risk of collision for all drivers and drivers with diabetes.

Any medical contact could represent an opportunity to detect medical conditions that put older drivers at higher risk of collision.

However, further research is needed to assess the potential effectiveness and practical modalities of potential systematic screening programs to detect unsafe driving due to medical conditions.

COMPETING INTEREST

The authors declare that they have no competing interests.

EXCLUSIVE LICENSE

REFERENCES

1 Organisation for Economic Co-operation and Development (OECD). Expert Group report: Ageing and Transport: mobility needs and safety issues; 2001. http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=/772001051P1 (accessed August 2007).

2 Dellinger AM, Langlois JA, Li G. Fatal crashes among older drivers: decomposition of rates into contributing factors. *Am J Epidemiol* 2002;**155**(3):234-41.

3 Lyman S, Ferguson SA, Braver ER, et al. Older driver involvements in police reported crashes and fatal crashes: trends and projections. *Inj Prev* 2002;**8**(2):116-20.

4 Universal Quebec Automobile Insurance Agency SAAQ. Statistics report 2005: accidents and driving license. http://www.saaq.gouv.qc.ca/publications/dossiers_etudes/dossier_bilan2005.pdf (accessed 15 Feb 2005).

5 Statistique Canada, Division de la démographie. Estimations de la population. Quebec Institute of Statistics; 2005. http://www.stat.gouv.qc.ca/. (accessed 15 Feb 2005).

6 Foley DJ, Wallace RB, Eberhard J. Risk factors for motor vehicle crashes among older drivers in a rural community. *J Am Geriatr Soc* 1995;**43**(7):776-81.

7 Cerrelli EC. Research note: crash data and rates for age-sex groups of drivers, 1994. Washington, DC: US Department of Transportation, National Highway Traffic Safety Administration, 1995.

8 Evans L. Risks older drivers face themselves and threats they pose to other road users. *Int J Epidemiol* 2000;**29**(2):315-22.

9 Hing JY, Stamatiadis N, Aultman-Hall L. Evaluating the impact of passengers on the safety of older drivers. *J Safety Res* 2003;**34**(4):343-51.

10 Khattak AJ, Pawlovich MD, Souleyrette RR, et al. Factors related to more severe older driver traffic crash injuries. *Journal of Transportation Engineering* 2002;**128**:243-49.

11 Marottoli RA. Driving safety in elderly individuals. *Conn Med* 1993;**57**(5):277-80.

12 Adler G, Rottunda S, Dysken M. The older driver with dementia: an updated literature review. *J Safety Res* 2005;**36**(4):399-407.

13 Retchin SM, Anapolle J. An overview of the older driver. *Clin Geriatr Med* 1993;**9**(2):279-96.

14 Withaar FK, Brouwer WH, van Zomeren AH. Fitness to drive in older drivers with cognitive impairment. *J Int Neuropsychol Soc* 2000;**6**(4):480-90.

15 Dubinsky RM, Stein AC, Lyons K. Practice parameter: risk of driving and Alzheimer's disease (an evidence-based review): report of the quality standards subcommittee of the American Academy of Neurology. *Neurology* 2000;**54**(12):2205-11.

16 Grabowski DC, Morrisey MA. The effect of state regulations on motor vehicle fatalities for younger and older drivers: a review and analysis. *Milbank Q* 2001;**79**(4):517-45.

17 Formisano R, Bivona U, Brunelli S, et al. A preliminary investigation of road traffic accident rate after severe brain injury. *Brain Inj* 2005;**19**(3):159-63.

18 Leon-Carrion J, Dominguez-Morales MR, Martin JM. Driving with cognitive deficits: neurorehabilitation and legal measures are needed for driving again after severe traumatic brain injury. *Brain Inj* 2005;**19**(3):213-9.

19 Canadian Medical Association. Determining Medical Fitness to Operate Motor Vehicles. CMA Driver's Guide, 7th Edition; 2006. http://www.cma.ca/index.cfm/ci_id/18223/la_id/1.htm (accessed June 2007).

20 Austroads Inc. Assessing Fitness to Drive for Commercial and Private Vehicle Drivers. 3rd Edition; 2003. http://www.austroads.com.au/upload_files/docs/AFTD%202003-F_A-WEBREV1.pdf (accessed June 2007).

21 Wang C, Kosinski C, Schwartzberg J, *et al*. Physician's Guide to Assessing and Counseling Older Drivers. Washington, DC: National Highway Traffic Safety Administration; 2003. http://www.ama-assn.org/ama/pub/category/10791.html (accessed June 2007).

22 White S, O'Neill D. Health and relicensing policies for older drivers in the European union. *Gerontology* 2000;**46**(3):146-52.

23 Grabowski DC, Campbell CM, Morrisey MA. Elderly licensure laws and motor vehicle fatalities. *JAMA* 2004;**291**(23):2840-6.

24 Langford J, Fitzharris M, Newstead S, et al. Some consequences of different older driver licensing procedures in Australia. *Accid Anal Prev* 2004;**36**(6):993-1001.

25 Owsley C, McGwin G, Jr., Phillips JM, et al. Impact of an educational program on the safety of high-risk, visually impaired, older drivers. *Am J Prev Med* 2004;**26**(3):222-9.

26 Maclure M. The case-crossover design: a method for studying transient effects on the risk of acute events. *Am J Epidemiol* 1991;**133**(2):144-53.

27 Horan JM, Mallonee S. Injury surveillance. *Epidemiol Rev* 2003;**25**:24-42.

28 Stork AD, van Haeften TW, Veneman TF. Diabetes and driving: desired data, research methods and their pitfalls, current knowledge, and future research. *Diabetes Care* 2006;**29**(8):1942-9.

29 Greenland S. Confounding and exposure trends in case-crossover and case-time-control designs. *Epidemiology* 1996;**7**(3):231-9.

30 Maclure M, Mittleman MA. Should we use a case-crossover design? *Annu Rev Public Health* 2000;**21**:193-221.

31 Baldock MR, Mathias JL, McLean AJ, et al. Self-regulation of driving and its relationship to driving ability among older adults. *Accid Anal Prev* 2006;**38**(5):1038-45.

32 Charlton JL, Oxley J, Fildes B, *et al*. Self-regulatory behaviours of older drivers. *Annu Proc Assoc Adv Automot Med* 2003;**47**:181-94.

33 Carr D, Schmader K, Bergman C, *et al*. A multidisciplinary approach in the evaluation of demented drivers referred to geriatric assessment centers. *J Am Geriatr Soc* 1991;**39**(11):1132-6.

34 Johansson K, Lundberg C. The 1994 International Consensus Conference on Dementia and Driving: a brief report. Swedish National Road Administration. *Alzheimer Dis Assoc Disord* 1997;**11** Suppl 1:62-9.

35 Dobbs BM, Carr DB, Morris JC. Evaluation and management of the driver with dementia. *Neurologist* 2002;**8**(2):61-70.

36 Reger MA, Welsh RK, Watson GS, *et al*. The relationship between neuropsychological functioning and driving ability in dementia: a meta-analysis. *Neuropsychology* 2004;**18**(1):85-93.

37 Snellgrove C. Cognitive screening for the safe driving competence of older people with mild cognitive impairment or early dementia. Australian Safety Bureau;2005. http://www.atsb.gov.au/publications/2005/pdf/cog_screen_old.pdf. (accessed 15 Feb 2005).

38 Marshall SC, Spasoff R, Nair R, *et al*. Restricted driver licensing for medical impairments: does it work? *Can Med Assoc J* 2002;**167**(7):747-51.

39 Fonda SJ, Wallace RB, Herzog AR. Changes in driving patterns and worsening depressive symptoms among older adults. *J Gerontol B Psychol Sci Soc Sci* 2001;**56**(6):S343-51.

40 Marottoli RA, de Leon CFM, Glass TA, et al. Consequences of driving cessation: decreased out-of-home activity levels. *J Gerontol B Psychol Sci Soc Sci* 2000;**55**(6):S334-40.

Figures

Figure 1: The case-crossover design used in the study of the association between road vehicle collisions and recent medical contacts in older drivers from the province of Quebec, Canada (1988 – 2000).

Figure 2: Numbers of drivers and collisions included in the study

Legend: * drivers excluded because aged less than 65 years: med=60, interquartile interval=57-62 and 52 subjects with coding errors; ** slight collisions and collisions resulting in material damages equal to Canadian $500 or less.