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Crash and burn? Vehicle, collision, and driver factors that influence motor vehicle collision fires

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ABSTRACT

A retrospective population-based case–control study was performed to determine the association between vehicle fires, and vehicle, collision, and driver factors on highways with a posted speed limit of at least 55 mph. Data were obtained from the Kentucky Collision Report Analysis for Safer Highways (CRASH) electronic files for 2000–2009 from the Kentucky State Police Records Sections. The results from the final multiple logistic regression show that large trucks were at a higher risk for a collision involving a fire than passenger vehicles and pickup trucks. When controlling for all other variables in the model, vehicles 6 years old and older, driving straight down the highway, and single vehicle collisions were also identified as factors that increase the risk of motor vehicle collision fires on roadways with a posted speed limit of ≥55 mph. Of the 2096 vehicles that caught fire, there were 632 (30%) non-fatally injured drivers and 224 (11%) fatally injured drivers. The results of this study have the potential to inform public health messages directed to the transportation industry, particularly semi truck drivers, in regard to fire risk.

1. Introduction

Approximately 31 highway fires are responded to every hour, and one person is killed every day due to vehicle fires in the US (National Fire Protection Association, 2010). Between the years 2003 and 2007, it was estimated that there were approximately 287,000 vehicle fires, 1525 injuries, and 480 deaths annually associated with vehicle fires. Of the vehicle fires responded to by emergency personnel, approximately three-quarters were due to mechanical or electrical failures or malfunctions. Collisions accounted for only 3% of all vehicle fires but for over half of the deaths (58%). Intentional vehicle fires were a factor in about 8% of all vehicle fires and vehicle fire deaths.

Vehicle crashes that result in fire have been associated with severe injuries (Zhu and Srinivasan, 2011; Majdzadeh et al., 2008; Singleton and Qin, 2004; Khattak et al., 2002). Injury severity has also been associated with the manner of collision such as head-on collisions (Singleton and Qin, 2004), and vehicle stiffness and frontal geometry (Blum et al., 2008). The Kentucky Fatality Assessment and Control Evaluation (FACE) program was established in 1994 to conduct surveillance of fatal work injuries and perform on-site investigations of worker deaths. Since the year 2005, the Kentucky – specific priority for worker fatality investigations has been the investigation of transportation industry fatalities. From 2005 to 2010, 60 fatal occupational large truck collisions were recorded in the FACE surveillance database and 14 FACE fatality reports were produced; of the 60 fatalities, 37% ($n = 22$) involved a vehicle fire.

Due to the high percentage of large truck collision fire fatalities investigated by the KY FACE program, the objective of this study was to determine if large trucks are more likely to catch fire than light trucks and passenger cars in collisions on Kentucky highways.

2. Study data

Data for the study were obtained from the Kentucky Collision Report Analysis for Safer Highways (CRASH) electronic files for 2000–2009 from the Kentucky State Police Records Sections which contained all reported crashes on public roadways in Kentucky. The electronic file received contained all motor vehicle collision information but excluded some personal identifiers. This study is part of the broad spectrum of the Kentucky Occupational Safety and Health Surveillance program which is approved by the University of Kentucky Institutional Review Board.

3. Methods

A retrospective population-based case–control study was conducted to evaluate if large trucks were more likely to catch on fire in a motor vehicle traffic collision on highways with a posted speed limit of at least 55 mph. For purposes of this study, "large

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trucks" included single unit trucks and semi trucks. "Light trucks" included vans, sports utility vehicles, and pickups. "Passenger cars" included passenger cars without a trailer. Passenger cars with trailers were not included in the study. Vehicles such as buses, emergency vehicles, farm tractors and/or farm equipment, go-carts, bicycles, military vehicles, motorcycles, motor homes/recreational vehicles, motor scooters, railroad trains, animals/animal drawn vehicles, school buses, and taxicabs were excluded from the analysis.

The selection of cases and controls from the CRASH electronic files was based on the outcome "fire", that pertains to each unit involved in the traffic collision as recorded in the field "Fire" in the Traffic Collision report. Cases were selected from all those electronic CRASH records with the "fire" variable recorded as "yes", regardless of whether the fire was the most harmful event. Controls were selected from all those CRASH records with the "fire" variable coded as "no". There was <1% missing data for the "fire" variable within the electronic CRASH dataset.

To be considered a case or control, the following collision inclusion criteria were used: (1) posted speed limit equal to or greater than 55 mph on the highway; (2) vehicles NOT in a parked position at the time of the collision (i.e., vehicle parked on the side of the 55 mph highway were not included); and (3) only large trucks, light trucks, and passenger cars were included in the study. *Cases* were defined as all vehicles (large trucks, light trucks, and passenger cars) that caught fire after a motor vehicle collision ($n = 2096$) on a highway with a posted speed limit of 55 mph or greater. *Controls* were a random sample of 2096 vehicles (large trucks, light trucks, and passenger cars) that were involved in a motor vehicle collision on highways with a posted speed limit of 55 mph or greater and did not catch fire.

To assess the strength of the association between vehicle type and the outcome of catching on fire in a motor vehicle collision, possible confounders and effect modifiers were accounted for. Based on our previous studies (Bunn et al., 2005, 2009) and others (Robertson, 1993; Blum et al., 2008), and the results of our FACE semi truck fatality investigations, we believed that there were vehicle, collision, and driver risk factors that could be causally associated with the risk of catching fire. The following vehicle, collision, and driver factors were included in the analysis: (1) pre-collision action (going straight forward, slowing or stopping, turning); (2) manner of collision (head-on collisions, single collision, etc.); (3) age of vehicle (≤5 years or ≥6 years); and (4) first area of contact in a collision (front or back bumpers or sides).

To test for an association between driver, collision, and vehicle risk factors and the outcome of the vehicle catching fire in a collision, a chi-square test was performed on the data. A logistic regression model was utilized and confounding factors were controlled for to assess whether any of the driver, collision, or vehicle factors affected the relationship between vehicle type and the vehicle catching fire in a collision. The statistical analysis included a SAS® *proc logistic* with a stepwise selection procedure. Reference coding for the categorical variables (where one level of the classification variable is designated as the reference level) was utilized (option/*param* = *ref* in the *class* statement of *proc logistic*).

Based on the results, none of the three-way interaction terms involving the exposure variable (type of vehicle) was significant. The results of the two-way interactions involving the "type of vehicle" variable determined that the manner of collision and the age of the vehicle were significant effect modifiers and the corresponding interaction terms were included in the final regression model:

$$\log\left[\frac{p_i}{1-p_i}\right] = \beta_0 + \sum_{j=1}^{k}\beta_j x_{ij}.$$

Here p_i, $i = 1, \ldots, n$ is the probability that the ith vehicle catches on fire in a collision, n is the total number of vehicles (observations) in the model, β_0 is a constant, and β_j, $j = 1, \ldots, k$ is the coefficient of the jth predictor variable. The reference coding in SAS is equivalent to creating a dummy variable for each level of a categorical variable except for the reference level. The following 13 dummy variables describe the final multiple logistic regression model for our study (therefore, $k = 13$ predictor variables in the final model): $x_{i1} = 1$ if the ith vehicle was a large truck, 0 – otherwise; $x_{i2} = 1$ if the ith vehicle was going straight forward, 0 – otherwise; $x_{i3} = 1$ if the ith vehicle was slowing or stopping, 0 – otherwise; $x_{i4} = 1$ if the ith vehicle had a precollision action classified as "other", 0 – otherwise; $x_{i5} = 1$ if the ith vehicle was 6+ years old, 0 – otherwise; $x_{i6} = 1$ if the first area of contact for the ith vehicle was back bumper/sleeper berth, 0 – otherwise; $x_{i7} = 1$ if the first area of contact for the ith vehicle was "front", 0 – otherwise; $x_{i8} = 1$ if the first area of contact for the ith vehicle was "front bumper", 0 – otherwise; $x_{i9} = 1$ if the manner of collision for the ith vehicle was "head on", 0 – otherwise; $x_{i10} = 1$ if the manner of collision for the ith vehicle was "single vehicle", 0 – otherwise; $x_{i11} = 1$ if the ith vehicle was a large truck and the manner of collision was "head on", 0 – otherwise; $x_{i12} = 1$ if the ith vehicle was a large truck and the manner of collision was "single vehicle", 0 – otherwise; $x_{i13} = 1$ if the ith vehicle was a large truck and the age was 6+ years, 0 – otherwise.

By using reference coding, the exponent of the parameter β_j estimate is interpreted as the odds ratio (OR) between that level of the risk factor and the reference level (when the factor is not involved in interactions). For example, $\exp(\beta_2)$ is interpreted as the OR for a vehicle going straight forward vs. a turning vehicle to catch on fire in a collision (controlling for all other variables in the model). When the risk factor participates in significant interactions, the odds ratio is an exponent of the sum of the estimated coefficient for the main effect of the risk factor and estimated coefficients for the interaction terms involving the risk factor. For example, $\exp(\beta_1 + \beta_{12} + \beta_{13})$ is interpreted as the OR for a large truck vs. light truck/passenger car to catch on fire in a "single vehicle" collision when the vehicles are 6+ years old (controlling for the rest of the variables in the model, i.e., assuming the vehicles had the same first area of contact and manner of collision). The statement *oddsratio* in *proc logistic* was used to calculate the OR for the variable "vehicle type" at each level of the variables "age of the vehicle" and "manner of collision".

To assess how well the final model fits the data, classification tables of the predicted and actual outcomes were created, the Hosmer–Lemeshow goodness-of-fit test was performed (option *lackfit* in the *model* statement in *proc logistic*), and the max-rescaled R^2 was calculated (option *rsq* in the *model* statement in *proc logistic*). Regression diagnostic statistics and plots were used to identify influential observations and outliers (Hosmer and Lemeshow, 2000).

To calculate Kentucky total vehicle fire rates, numerators were calculated for large trucks, and for light trucks and passenger cars in all collisions on the Kentucky highway (including all posted speed limits and parked vehicles). The denominators were tabulated based on all collisions contained in the CRASH dataset for large trucks (large truck vehicle fire rate denominator) and for light trucks and passenger cars (light truck/passenger car denominator).

4. Results

Statewide, the large truck vehicle fire rate significantly increased over the ten year span (Fig. 1) from 2000 to 2009. The light truck/passenger car vehicle fire also increased over the ten year period although it was not a significant increase. In 2009, the large truck fire rate was 113% above the light truck/passenger car fire rate.

Table 1
Motor vehicle collisions by vehicle type, 2000–2009.

Collision characteristics	Cases: (n = 2096) motor vehicle fires n (%)	Controls: (n = 2096) motor vehicles that did not catch on fire n (%)
Vehicle category/type		
Large trucks	289 (13.9%)	173 (8.3%)
Light trucks/passenger cars	1796 (86.1%)	1922 (91.7%)
Vehicle unit type-detailed		
Light trucks/passenger cars		
Passenger vehicle	975 (46.5%)	1125 (53.7%)
Light truck	821 (39.2%)	797 (38.0%)
Large trucks		
Truck and trailer	66 (3.1%)	40 (1.9%)
Truck-single unit	71 (3.4%)	57 (2.7%)
Truck tractor and semi-trailer	152 (7.3%)	76 (3.6%)
Truck-other combination	11 (0.5%)	1 (<0.1%)

In our study, the highest percentage of vehicles that caught fire after a motor vehicle collision were large trucks (n = 289, 13.9%) compared to 8.3% in the control group (Table 1) that were large trucks that did not catch fire. Semi trucks accounted for 7.3% of the vehicles that caught on fire, whereas, only 3.6% of the controls (those that did not catch fire) were semi trucks. When a crude odds ratio was calculated as a measure of the association between vehicle type and catching fire after a motor vehicle collision, the crude odds ratio was 1.79 with a 95% confidence interval of 1.46–2.18. Therefore, there was a significant association between the type of vehicle and catching fire after a motor vehicle collision. Of the large trucks that caught on fire, only 13 (0.6%) were carrying hazardous materials.

The impact of fires on the drivers of vehicles who caught fire in a collision cannot be overstated (Table 2). Driver injuries were much more severe among drivers whose vehicles caught fire in a motor vehicle collision, possibly due to burn injuries. More of the injured drivers involved in motor vehicle fires received multiple injuries (17%) compared to 4% of the drivers in motor vehicle collisions that did not result in a fire. More drivers died (10.7%), or received incapacitating injuries (9%) in vehicles that caught fire in a collision than drivers whose vehicles did not catch on fire (0.6% and 3%, respectively). One-quarter of the drivers whose vehicles caught fire in a collision were transported from the scene by an emergency vehicle; 16% of the drivers whose vehicles did not catch fire were transported from the scene in an emergency vehicle. Approximately 9% of the drivers who were in collisions that caught fire were removed from the scene by a coroner or a funeral home compared to 0.5% of the drivers whose vehicle did not catch on fire. Also, significantly more drivers were transported from the scene in a helicopter or other air vehicle when a fire was involved (6.4% of cases compared to 1% of controls), probably due to the severity and type of injuries (burns most likely). The "injured removed by" variable was not coded for 59% of the cases and 75% of the control groups. The uncoded "injured removed by" variable corresponds to the "injury severity" variable coded as "none" (58% for the cases and 79% for the controls), which indicates no associated injuries and no removal from the scene of the collision by first responders. When driver factors were examined, restraint use by drivers in vehicles that caught fires was lower compared to the drivers in vehicles that did not catch fire (83.4% of cases compared to 91.9% of controls). It should be noted that restraint usage is self-reported, therefore, this comparison may be an overestimate of the true percentage of restrained drivers in both the cases and controls.

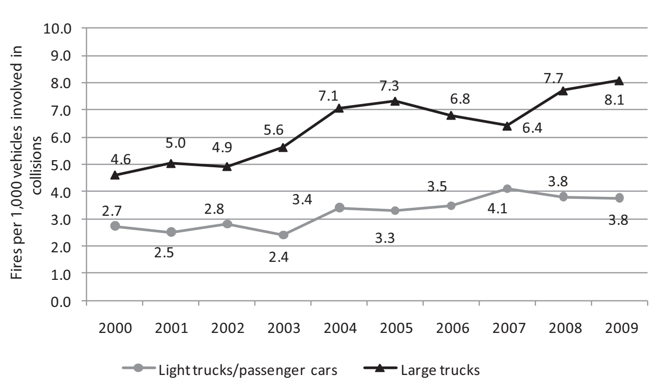

Fig. 1. Vehicle fire rates due to motor vehicle collisions, 2000–2009.

A data based association was tested between vehicle, collision, and driver risk factors and the outcome of the vehicle catching on fire (Table 3) using a chi-square test. The age of the vehicle, the pre-collision action, the manner of collision, and the area of first contact on the vehicle were all associated with a vehicle catching on fire in a collision in a 55 mph or greater speed zone. A significantly larger percentage of the motor vehicles were 6 years of age or older (69%) that caught fire (cases) when compared to the vehicles in the control group (59%). A larger percentage of the drivers were traveling straight forward in the vehicles that caught fire (87% compared to 67% in the vehicles that did not catch fire). Three-quarters of the cases (the vehicles that caught fire) were single vehicle crashes, whereas only 31% of the controls involved single vehicle crashes. The front of the vehicle was impacted in approximately two-thirds of the motor vehicle fire cases compared to 39% in the controls.

A multiple logistic regression was performed to estimate the association between the vehicle catching fire in a collision and the type of vehicle (Table 4) controlling for the vehicle, collision, and driver factors in Table 3. Table 4 provides information on the parameter estimates for the logistic regression, modeling the probability of catching on fire during a collision. The exposure variable of interest is the type of vehicle. Related risk factors and significant interactions are listed in the table. Parameter estimates for the logistic regression show that large trucks, traveling straight forward, vehicles 6 years of age and older, impaction of the front of the vehicle or bumpers, head-on collisions, and single vehicle collisions are significantly associated with a vehicle catching fire in a collision. There were significant two-way interactions involving the exposure variable of interest: (1) vehicle type $\times$ manner of collision; and (2) vehicle type $\times$ age of the vehicle.

Table 5 provides estimates for the odds ratios for large trucks vs. light trucks and passenger cars and their 95% confidence intervals at different levels for the manner of collision and vehicle age variables. The results show that large trucks, no matter the age of the vehicle and manner of collision, have a higher odds of catching on fire in motor vehicle collisions on highways with a posted speed limit of 55 mph and higher when compared to light trucks and passenger

Table 2
Motor vehicle collisions by driver injury factors, 2000–2009.

Driver injury characteristics	Cases: (n = 2096) motor vehicle fires n (%)	Controls: (n = 2096) motor vehicles that did not catch fire n (%)
Restraint use		
Shoulder/lap belt	1748 (83.4%)	1926 (91.9%)
Installed/not in use	328 (15.7%)	150 (7.2%)
Injury location		
Head/face/neck	212 (10.1%)	183 (8.7%)
Chest/back/abdomen/pelvis	129 (6.2%)	95 (4.5%)
Arms/hands/legs/feet	159 (7.6%)	64 (3.1%)
Multiple/entire body	356 (17.0%)	83 (4.0%)
Number missing (~non-injured)	1240 (59.2%)	1671 (79.7%)
Injury severity		
Fatal	224 (10.7%)	12 (0.6%)
Incapacitating	188 (9.0%)	63 (3.0%)
Non-incapacitating	249 (9.0%)	155 (7.4%)
Possible injury	195 (9.3%)	196 (9.4%)
None	1225 (58.4%)	1647 (78.6%)
Injured removed by		
Funeral home/coroner	192 (9.2%)	10 (0.5%)
Helicopter/other air vehicle	134 (6.4%)	21 (1.0%)
Municipal/county emergency vehicle	516 (24.6%)	346 (16.5%)
Police ambulance/private ambulance	141 (6.7%)	104 (5.0%)
Private vehicle	49 (2.3%)	69 (3.3%)
Missing/other	1229 (58.6%)	1572 (75.0%)

cars. In head on collisions involving newer vehicles (≤5 years), the odds of a large truck vs. a light truck or passenger car catching fire is 7.27, 95% CI = [2.33, 22.72]; for older vehicle head on collisions (6+ years), the odds ratio is 4.28, 95% CI = [1.35, 13.56]. In single vehicle collisions involving newer vehicles (≤5 years), the odds of a large truck vs. a light truck or passenger car catching fire is 6.28, 95% CI = [3.76, 10.47]; the odds ratio is 3.69, 95% CI = [2.25, 6.05] for older (6+ years) single vehicle collisions.

The area under the receiver operating characteristic (ROC) curve was 81%. The predictive power of the model measured by max-rescaled R-Square was 0.38. The regression diagnostic plot of the change in the deviance (DIFDEV) by predicted probabilities showed approximately 60 observations with residuals between 4 and 6 that seemed to be poorly fit. Most of them were cases, passenger vehicles with "other" manner of collision and various values of the other covariates that had low estimated probabilities to catch on fire. The poorly fit controls (13 controls) were large trucks, going straight forward, in single vehicle collisions, with "front" or "other" area of first contact and, therefore, with a high predicted probability for catching on fire. We investigated the observations with a poor fit and kept the plausible observations in the model. The plot of the difference in Pearson Chi-Square statistics (DIFCHISQ) by predicted probabilities where the plotting symbol was a bubble with a size proportional to the confidence interval displacement diagnostic (C) was used to identify influential observations but no observations were considered a reason for concern or exclusion. The model fit was acceptable according to the Hosmer–Lemeshow goodness-of-fit test (p-value = 0.17).

Table 3
Risk factors associated with vehicles catching on fire in a collision, 2000–2009.

Collision characteristics	Cases: (n = 2096) motor vehicles fires n (%)	Controls: (n = 2096) motor vehicles that did not catch on fire n (%)	p-value
Age of vehicle			
≤5 years	643 (30.7%)	845 (40.3%)	<0.0001
6+ years	1445 (68.9%)	1243 (59.3%)	
Missing values	8 (0.4%)	8 (0.4%)	
Pre-collision action			
Going straight forward	1816 (86.6%)	1407 (67.1%)	<0.0001
Turns	37 (1.8%)	151 (7.2%)	
Slowing or stopping	58 (2.8%)	178 (8.5%)	
Other	185 (8.8%)	360 (17.2%)	
Missing values	0	0	
Manner of collision			
Head on	158 (7.5%)	95 (4.5%)	<0.0001
Single vehicle	1575 (75.1%)	641 (30.6%)	
Other	363 (17.3%)	1360 (64.9%)	
Missing	0	0	
First area of contact			
Back bumpers/sleeper berth	33 (1.6%)	124 (5.9%)	<0.0001
Front of vehicle	1382 (65.9%)	816 (38.9%)	
Front bumper	143 (6.8%)	388 (18.5%)	
Other	538 (25.7%)	768 (36.6%)	
Missing	0	0	

Table 4
Multiple logistic regression of motor vehicle collision fires-parameter estimates.

Parameter	Categories	Estimated parameter β_j	Standard error of the parameter	Pr > Chi Sq
Intercept		−2.3188	0.2286	<0.0001
Vehicle type	Large trucks	0.9849	0.2083	<0.0001
	Light trucks/passenger cars	Ref		
Pre-collision action	Going straight forward	0.5844	0.2179	0.0073
	Slowing or stopping	0.0905	0.2749	0.7420
	Other	0.3257	0.2370	0.1693
	Turns	Ref		
Age of vehicle	6+ years old	0.4732	0.0826	<0.0001
	≤5 years old	Ref		
First area of contact	Back bumper/sleeper berth	−0.9810	0.2450	<0.0001
	Front	0.6243	0.0860	<0.0001
	Front bumper	−0.8472	0.1292	<0.0001
	Other	Ref		
Manner of collision	Head on	1.4945	0.1599	<0.0001
	Single vehicle	2.0141	0.0867	<0.0001
	Other	Ref		
Manner of collision × vehicle type	Head on-large trucks	0.9995	0.5942	0.0926
	Single vehicle-large trucks	0.8521	0.2789	0.0022
Age of vehicle × vehicle type	6+ years old-large trucks	−0.5316	0.2599	0.0408

5. Discussion

The results of this study show that large trucks, semi trucks in particular, are more likely to catch fire in higher speed (55 mph speed zones and higher) vehicle crashes compared to light trucks and passenger cars. Older vehicles were also more likely to catch on fire in a motor vehicle collision. Single vehicle and head on collisions increase the probability that the collision will result in a fire. When compared to light trucks and passenger cars, large trucks were more likely to catch fire in a motor vehicle collision, especially in head-on and single vehicle crashes.

A higher percentage of the drivers of the vehicles that caught fire were not wearing their safety restraints during the collision compared to those drivers whose vehicle did not catch fire. Drivers in motor vehicle fires also received a higher percentage of incapacitating and fatal injuries, and a higher percentage were removed from the crash scene by coroners, funeral homes, emergency helicopters and emergency vehicles.

There could be many reasons for large trucks being more likely to catch fire in a motor vehicle collision. The average large truck weight (typically up to 80,000 pounds) can result in a greater impact force in collisions with a fixed object. When comparing light trucks and passenger cars to large trucks, the heavier the vehicle mass, the greater the impact force is when traveling at an equivalent speed. Also, the larger fuel capacity and hazardous material carried by large trucks could affect the vehicle's flammability. Large trucks typically house two 150 gallon diesel fuel tanks in the tractor, and another 50 gallon fuel tank if the tractor is hauling a refrigerated trailer.

There are fuel tank placement differences between large trucks, and light trucks and passenger cars, which could account for fire likelihood differences between vehicle types in head-on and single vehicle collisions. Increased exposure occurs in large trucks because the two fuel tanks on the semi tractor are exposed under the cab and are located directly behind the front axle. In light trucks and passenger cars, the fuel tank is typically placed above or in front of the rear axle; the fuel tank is more protected in passenger vehicles and light trucks and is not as exposed as the fuel tanks on semi tractors. In a study by Robertson (1993), the author determined that rear-end collision fires were reduced by 77% if the fuel tank was placed directly above or in front of the rear axle in cars. In addition, large trucks have a crossover line between tanks in the tractor that is protected by a length of angle iron. If the angle iron is compromised, the crossover line is then susceptible to failure (e.g., tears, rupture, puncture) and may increase the risk of catching fire in a motor vehicle collision.

Cars have been equipped with an inertia fuel switch (IFS) since the 1980s to cut off the flow of fuel in the event of a collision or rollover. In newer model cars and light trucks, the IFS is controlled by the vehicle's computer processor that operates the door locks, air bags, etc. The software has sensors that switch the fuel pump off in a crash. The electronic throttle shuts off the flow of gas while allowing the driver to still steer the vehicle. In semi trucks, a manual cutoff switch is available for each tank and is an option that may be purchased at the time of sale. The cutoff switch shuts off the flow of fuel from the tank until repairs can be made. Shutting off the fuel flow may be necessary if there is a rupture to the tank. According to one semi truck dealer contacted, approximately 30% of buyers purchase the manual cutoff switch option. An automatic inertia fuel switch, similar to those in passenger vehicles, should be made available as standard equipment in large trucks. In one of the Kentucky FACE fatality reports (#07KY070) (available at http://www.kiprc.uky.edu/projects/KOSHS/rep_mv.html), the driver burned to death after a fuel line was compromised on the refrigeration unit and dripped onto the exhaust pipe of the semi tractor. One of the recommendations that the Kentucky FACE

Table 5
Multiple logistic regression of motor vehicle collision fires – large trucks vs. light trucks/passenger cars odds ratio estimates by manner of collision and vehicle age.

Wald confidence interval for odds ratio			
	Estimate	95% Confidence limits	
Large trucks vs. light trucks/passenger cars, manner of collision = head on, vehicle age = 6+ years old	4.28	1.35	13.56
Large trucks vs. light trucks/passenger cars, manner of collision = head on, vehicle age ≤ 5 years old	7.27	2.33	22.72
Large trucks vs. light trucks/passenger cars, manner of collision = other, vehicle age = 6+ years old	1.57	1.02	2.43
Large trucks vs. light trucks/passenger cars, manner of collision = other, vehicle age ≤ 5 years old	2.68	1.78	4.03
Large trucks vs. light trucks/passenger cars, manner of collision = single vehicle, vehicle age = 6+ years old	3.69	2.25	6.05
Large trucks vs. light trucks/passenger cars, manner of collision = single vehicle, vehicle age ≤ 5 years old	6.28	3.76	10.47

program made was that manufacturers of commercial refrigerated trailers should consider a sensor design that shuts off the fuel supply to the refrigeration unit when the fuel line is compromised.

Differences in geometric design, including vehicle stiffness, could also account for differences in vehicle risk for catching fire in high speed limit (≥55 mph) motor vehicle collisions. Blum et al. (2008) determined that increased vehicle stiffness and weight were associated with less severe injuries in cars. In semi truck collisions, the structural integrity of the semi truck cab is critical in its crashworthiness during frontal crashes with a fixed object. It has been estimated that having a crush space of at least 24 in. within the semi truck cab requires approximately 180,000 lbs of crush strength (Krishnaswami and Blower, 2003). Krishnaswami and Blower (2003), stated that increasing the frontal crash strength of semi truck cabs to 180,000 lbs would provide protection from intrusion (deformation) in approximately 66% of all frontal semi truck crashes. Currently, passenger cars have approximately 39 in. of crush space. In addition, fire resistant materials should be incorporated into the semi truck cab design. Fire resistant shields and ceramic coatings could be used to help protect the engine from the interior of the cab during a fire.

Driver distraction and sleepiness could contribute to an increased risk for a large truck to catch fire and severe driver injuries because of the possibility of higher impact crashes if the driver falls asleep and no evasive maneuvers are performed to avoid fixed objects or vehicle rollovers. Driver distraction has been associated with severe large truck crashes (Zhu and Srinivasan, 2011). In a previous study using Kentucky CRASH data, we found that driver sleepiness/fatigue, distraction/inattention, and nonuse of safety belts increased the odds for a fatal commercial vehicle collision (Bunn et al., 2005). In our current study results, more large trucks that caught fire were driven by drivers who were fatigued or fell asleep at the wheel compared to those drivers whose vehicle did not catch fire in a motor vehicle collision. Fourteen (5%) of the large truck drivers whose vehicle caught fire were coded as /fatigued or falling asleep at the wheel and 33 (11%) were coded as distracted/inattentive on the police report. Less than one percent of the drivers were coded as fatigued/falling asleep and 21% coded as distracted/inattentive in the control vehicles that did not catch fire.

At least thirty-two percent of the drivers whose vehicle caught fire in a motor vehicle collision received either non-fatal or fatal injuries and 6% were removed from the scene with an emergency helicopter, possibly due to burns that require Level I trauma center treatment. Quick emergency response is necessary to decrease the morbidity and mortality associated with fire-related collisions, especially in a rural state such as Kentucky. In a study assessing emergency medical services (EMS) prehospital time, increased EMS prehospital time was associated with higher mortality in motor vehicle crashes in rural areas vs. urban areas (Gonzalez et al., 2009). Rapid access to Level I trauma centers should be a priority for fire-related motor vehicle collision response. Identification and prioritization of fire-related crashes that differ from those collisions that do not result in a fire or injuries will optimize rapid EMS response and the use of EMS resources.

There are a number of limitations of the present study. Electronic CRASH data does not have narrative information to ascertain exactly where the fire started in the vehicle after a motor vehicle collision, which would be useful to determine the root cause of the fire. Second, this study did not examine makes and models of the vehicles involved in the fire-related crashes in order to assess vehicle crush and vehicle stiffness differences between vehicle types. Last, information on whether safety features, such as the angle iron that protects the crossover pipe between fuel tanks, were tampered with by the drivers or were compromised in the vehicle crash was not available for analysis.

6. Conclusions

This paper illustrates the further need for enhanced vehicle and roadway design fire safety features, especially on large trucks. In Kentucky alone for the 10 year study period, over 2000 vehicle fires occurred (approximately 210 per year) in collisions on highways with posted speed limits of 55 mph or higher. Roadway fire safety features could be enhanced through the increased use of interventions: (1) rigid roadside barriers (test level [TL]-4 or TL-5) to contain and redirect semi trucks from leaving the roadway; (2) median barriers on highways with medians less than 50 feet and less than 20,000 vehicles per day that will prevent cross-over collisions; and (3) the use of semi-rigid rail systems to adequately deflect semi trucks without snagging the vehicle or the elimination of bridge abutments next to interstate highways (American Association of State Highway and Transportation Officials, 2006). Also, rapid emergency medical response is required for the treatment of severe injuries associated with the vehicles that catch fire in a motor vehicle collision. Rapid access to nearby Level I trauma centers for the treatment of motor vehicle fire-related burns is recommended. The results of this study have the potential to inform public health messages directed to the transportation industry in regard to fire risk, particularly to semi truck drivers.

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