Liver transplantation in Indian Armed Forces—initial experience

Brig Anupam Saha*, Surg Capt CS Naidu, VSM[†], Brig GS Ramesh[#], Surg Capt Joy Chatterjee[‡], Col Pankaj Puri[§],
Gp Capt Bhaskar Nandi^{**}, Lt Col Pradhi Nambiar[‡], Wg Cdr Renu Madan^{##}

ABSTRACT

BACKGROUND

This study retrospectively analyses the initial experience of liver transplantation (LT) in the Indian Armed Forces.

METHOD

Fifty-three patients underwent LT at Army Hospital (R&R) Delhi Cantt. between March 2007 and March 2011. Of these 35 patients underwent deceased donor liver transplantation (DDLT) and living donor liver transplantation (LDLT) was carried out in 18 patients. The surgical techniques, complications and mortality were analysed.

RESULTS

A high consent rate of 35.9% for organ donation was achieved by the Armed Forces Organ Retrieval and Transplantation Authority (AORTA). Biliary complications occurred in five patients (9.4%). However, most of them could be managed by endoscopic interventions. Hepatic artery thrombosis (HAT) occurred in five patients (9.4%). Of these, two DDLT grafts were revascularised following HAT, by creating extra-anatomic arterial conduits with excellent outcome. The overall mortality was 18.8% ($n=10$). There was no significant difference in the overall complications or mortality in patients undergoing DDLT or LDLT.

CONCLUSION

The overall survival and morbidity in this study is comparable to those from other centres. Urgent revascularisation of grafts following HAT should be attempted as it can salvage grafts with satisfactory outcome. There is a reduction in the incidence of biliary complications with refinements in surgical techniques.

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Key Words: AORTA; DDLT; Indian Armed Forces; LDLT

*Commandant, Military Hospital, Agra, Agra Cantt. – 282001, [†]Senior Advisor (Surgery & GI Surgery), [#]Consultant (CTVS Anaesthesia), [§]**Senior Advisor, (Gastroenterology), [‡]Transplant Coordinator, ^{##}Classified Specialist (Pathology), Army Hospital (R&R), Delhi Cantt., New Delhi – 10, [‡]Senior Advisor (Paediatric Anaesthesia), INHS Asvini, Colaba, Mumbai.

Correspondence: Brig Anupam Saha, Commandant, Military Hospital, Agra, Agra Cantt. – 282001.
E-mail: anupam56@gmail.com

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INTRODUCTION

Orthotopic liver transplantation is the only therapeutic option for patients with end-stage liver disease (ESLD). In India, over 200,000 patients succumb to ESLD and its complications annually in India.¹ The first successful deceased donor liver transplantation (DDLT) in India was performed in 1998; however, it could not be sustained due to lack of deceased organ donors and lack of efforts to promote deceased organ donation. Scarcity of deceased donors gave an impetus to the growth of living donor liver transplantation (LDLT) in India.

In 2006 the Indian Armed Forces established the Armed Forces Organ Retrieval and Transplantation Authority (AORTA) which has been responsible for sensitising the Armed Forces clientele towards brain stem death and organ donation. The first DDLT in the Indian Armed Forces was performed on 8 March 2007 and the success of our DDLT programme has been a stimulus for the resurrection of DDLT in the country especially in South India.² Gaining from our experience in DDLT and persisting donor organ scarcity, we have established the LDLT programme too, especially to address the paediatric patients with ESLD.

MATERIALS AND METHOD

Between March 2007 and March 2011, 53 patients with ESLD underwent LT at Army Hospital (R&R) Delhi Cantt. Of these, 35 patients underwent DDLT and LDLT was carried out in 18 patients. In the DDLT group the mean age of patients was 35.2 years (14 months to 63 years) whereas in the LDLT group, the mean age was 21.6 years (six months to 61 years). All these recipients underwent investigations as per a standard protocol and were listed on the waiting list after discussions at multidisciplinary liver transplant meetings. The most common indication for transplantation was hepatitis B cirrhosis (35.8%), followed by cryptogenic cirrhosis (33.9%) (Figure 1). Nine recipients were in the paediatric age group ranging between six months and 12 years.

Thirty-six liver grafts were procured from brain dead donors of whom four grafts were retrieved at All India Institute of Medical Sciences (AIIMS), New Delhi. The remaining 32 liver grafts were donated at three service hospitals. In these hospitals 88 brain stem dead patients were counselled by AORTA³

Figure 1 Indications for liver transplant ($n=53$).
PFIC: progressive familial intrahepatic cholestasis.

Table 1 Extended criteria donors ($n=19$).

Expanded criteria	No. of patients
Age > 65 yr	4
Fatty liver > 30%	3
Moderate to high inotropes	15
HBcAg positive	1
ALT > 3 times upper limit of normal	4
Hypernatraemia	1
Revived cardiac arrest	1

ALT: alanine aminotransferase, HBcAg: hepatitis B core antigen.

and consent for multi-organ donation was obtained in 32 (35.9%) patients. Of these 36 liver grafts, two liver grafts were found unsuitable for transplantation due to fatty liver in one and undiagnosed colonic gangrene in the other. One donor liver was split in situ to transplant two recipients.

We have transplanted a high percentage of marginal donor liver grafts with good outcome.⁴ It is important to plan the use of these liver grafts judiciously to obtain the best results. Around 19 of the 34 livers (55.8%) were harvested from marginal or extended criteria donors (Table 1). Our policy has been to accept donor livers irrespective of age but in elderly donors we accept grafts with <30% fat, normal liver enzymes, and on low dose of ionotropes. The cold ischaemia time of these grafts is kept to the minimum to reduce the preservation injury.

THE SURGICAL TECHNIQUE

Deceased Donor Organ Retrieval

All liver graft retrievals were carried out by one organ retrieval team using the standard retrieval protocol. The status of liver was visually assessed and palpated for liver fat. We do not

perform any liver biopsy to assess for fatty liver. The presence of accessory or replaced hepatic arteries was noted.

After heparinisation of the donor (300 units/Kg body weight), aortic and superior mesenteric vein (SMV) cannulation is carried out followed by cold histidine tryptophan ketoglutarate (HTK) preservative solution perfusion at 4°C is started (6L HTK into aorta and 2L into portal vein) after clamping the supra celiac aorta and incising the supra hepatic inferior vena cava (IVC) for venting of blood. The donor liver is perfused with cold HTK for at least 15–20 minutes to ensure adequate cooling of the liver and washout of blood. Crushed sterile ice is placed around the liver for external cooling.

Rest of the dissection is carried out in the cold phase. The liver is harvested safeguarding it from any injury. The liver graft is perfused on the back table with cold HTK and placed in an ice box.

Living Donor Hepatectomy

The objective is to procure optimum liver grafts with the least morbidity to the donor. Our policy is to accept living donors between 18 years and 50 years of age with no co-morbidity. All donors are evaluated as per protocol. Liver size, steatosis, liver vascular, and biliary anatomy is obtained performing a computed tomographic (CT) angiography and magnetic resonance cholangiopancreatography (MRCP), and meticulous pre-operative planning is carried out. At our centre, the minimum acceptable residual liver volume in the donor is 35% of the total liver volume and the minimal acceptable graft volume is 1% of recipient body weight. Donor hepatectomy is carried out under low central venous pressure (CVP) and without inflow occlusion. Intra-operative cholangiogram is done to determine the site of bile duct transaction. Liver transection is carried out using ultrasonic aspirator. All hepatic veins of >5 mm draining the graft are safeguarded for later anastomosis in the recipient. In right lobe grafts, we do not harvest the middle hepatic vein (MHV) for donor safety. Instead we restore the drainage of segment V and VIII veins of the graft after lengthening them using interposition vein grafts. As a routine, following donor hepatectomy we perform methylene blue dye test to check for bile leaks from the cut surface of the residual liver. None of the donors required blood transfusion (Table 2).

Bench Surgery

Bench surgery is carried out to prepare the graft for implantation. The deceased donor liver graft is cleaned of extra tissues like diaphragm, right adrenal, etc. The hepatic artery and portal vein is carefully cleaned of all extraneous tissues. Ex situ splitting of donor liver, arterial and venous reconstructions are carried out on the bench if needed. In living donor liver grafts, interposition vein grafts are usually necessary to lengthen segment V and VIII veins for anastomosis using recipient's portal vein segments from the explanted liver or stored deceased donor iliac veins (Figure 2). Venoplasty of hepatic veins are often necessary to ensure good drainage of the graft which is critical to its survival. The bench surgery should be performed quickly to prevent warming of the organ.

Table 2 Living donor hepatectomy parameters.

Donor operation	No.	Surgery time (min)	Blood loss (mL)	Accessory hepatic artery anastomosis	Hepatic/segment V/VIII vein venoplasty	Two bile ducts in graft	Donor morbidity
Right hepatectomy	8	530	547	1	5	2	One bile leak Subsided on day four postoperatively
Left hepatectomy	5	493	560	1	2	–	–
Left lateral segment hepatectomy	5	482	235	1	3	–	–

Figure 2 Interposition vein grafts anastomosed to segment V and VIII hepatic veins in right lobe graft on the bench. **Figure 3** Piggyback technique of anastomosing donor inferior vena cava to recipient hepatic veins. **Figure 4** Completed portal vein and hepatic artery anastomosis. Bull dog clamp seen on the bile duct. **Figure 5** Well perfused liver graft at the end of surgery in the same patient.

The Recipient Surgery

Recipient hepatectomy is fraught with danger of massive blood loss due to portal hypertension and coagulopathy.⁵ Hence, we routinely place a 7.5F sheath in the internal jugular in addition to a triple lumen catheter. Cell Saver and rapid infusers is used routinely. Tranexamic acid infusion is employed to combat fibrinolysis and excessive bleeding.⁶ We routinely

use a Mercedes Benz incision which gives a wide exposure. Good electrocautery equipment is essential and the author finds the monopolar electrocautery forceps ideal to keep blood loss to the minimum.

In DDLT, there are two implantation techniques. Piggyback technique is preferred⁷ over the standard caval replacement technique as it avoids clamping of the suprahepatic vena cava.

Clamping and dividing the portal vein should be delayed as far as possible to avoid splanchnic congestion and bowel oedema. We find early creation of a temporary portocaval shunt very useful to reduce bleeding as well as avoid splanchnic congestion.⁸

The first anastomosis at implantation of the graft is the out-flow anastomosis (Figure 3). The next anastomosis is the portal vein anastomosis and it is important to ensure no redundancy and anastomotic narrowing is avoided by leaving a growth factor.

Reperfusion of the graft is done by first releasing the IVC or hepatic vein clamp allowing retrograde perfusion before releasing the portal vein clamp and portal blood flow. Severe post reperfusion syndrome with haemodynamic instability and cardiac arrhythmias can occur at reperfusion.⁹ Any coagulation abnormality must be corrected with blood components and we find thromboelastography very useful to direct the use of blood components.¹⁰

After reperfusion of liver and achieving haemostasis, arterial anastomosis is performed (Figure 4). At our centre anastomosis is done using loupes with 3.5× magnification. Cholecystectomy is always carried out. Finally the biliary continuity is established with duct-to-duct biliary anastomosis to complete the transplant procedure (Figure 5). We do not use any biliary stents.¹¹ It is important to ensure freshening of the bile duct edges and avoid any redundancy. Roux-En-Y choledochojejunostomy is done when the recipient bile duct is not available.

Extra-anatomic Vascular Conduits

When the recipient hepatic artery is unsuitable for anastomosis either due to injury, intimal dissection or thrombosis, extra-anatomic vascular conduit is an effective method to restore arterial flow.^{12,13} In this series, six patients (18.7%) underwent seven extra-anatomic arterial conduits. Two vascular conduits were performed as graft salvage procedure following hepatic artery thrombosis (HAT) and the others underwent primary vascular conduits. Infra renal aortic conduits using harvested donor iliac arteries were performed in six patients. One patient underwent a supra celiac aortic conduit to salvage the graft following thrombosis of an infra renal conduit.

Six patients (18.7%) also had portal vein thrombosis (PVT), majority of them being Yerdell grade 1–2.¹⁴ Eversion thrombectomy was carried out in four patients. One patient with PVT extending behind the neck of pancreas underwent a jump graft from SMV using donor iliac vein graft. Another patient had complete thrombosis of the splenoportal axis and the donor portal vein was anastomosed with a collateral vein. One patient with postoperative PVT underwent emergency revascularisation with iliac vein conduit from the recipient SMV. There were no procedure-related complications in this group of patients.

Postoperative Care and Immunosuppression

Patients are weaned off assisted ventilation as soon as possible usually within 6–8 hours after surgery. Central venous pressure is kept low to ensure good drainage of the liver graft. It is important not to cause fluid overload in the postoperative period.¹⁵ Doppler ultrasound is done twice daily for seven days to assess

the vascular anastomotic patency. Infections are common in the early postoperative period and our protocol is to remove the central intravenous catheters and abdominal drains at the earliest.¹⁶ Albumin infusion and diuretics are useful to control ascites and high drain output which is common after LT. Patients are ambulated early and any localised collections are drained percutaneously. Whenever there is suspicion of HAT, urgent angiography is done to confirm the presence of HAT and emergency revascularisation of the graft is attempted.¹⁷ Standard immunosuppression protocol consists of inj Methylprednisolone during the an hepatic phase and then converting to oral prednisolone and tacrolimus (TAC) daily from the first postoperative day. Mycophenolate mofetil (MMF) is added when the thrombocytopenia resolves. The steroids are tapered off after three months. Frequent TAC blood levels needs to be obtained in the initial postoperative period.¹⁸

RESULTS

The follow-up in both groups of DDLT and LDLT ranged from two months to 48 months. In DDLT the preferred technique was the piggyback technique in 62.8% ($n=22$).

In LDLT group, all living donor grafts were >1% of recipient body weight (1.2–4.6%). Two left lateral segment grafts were reduced in situ for paediatric recipients. None of the living donors needed blood transfusion during donor hepatectomy. Donor complication occurred in only one donor who developed bile leak postoperatively which subsided spontaneously after four days and has been asymptomatic thereafter.

In recipients undergoing DDLT or LDLT, there was no significant difference in the intra-operative parameters except the operation time and shorter cold ischaemia time in LDLT. The average recipient intra-operative parameters are shown in Table 3.

Complications occurred in 15 recipients (28.3%) in our series. With vascular complications observed in seven recipients (13.2%). The most dreaded vascular complication is HAT which occurred in five recipients (9.4%). Biliary complications in the form of bile leaks and strictures occurred in five patients (9.4%). Long-term biliary complications in the form of anastomotic biliary strictures occurred in 7.5% of the recipients (Table 4).

Vascular Complications

Three patients (8.5%) in the DDLT group and two patients (11.1%) in the LDLT group developed HAT. In the DDLT group, both patients with HAT underwent emergency revascularisation of the graft with excellent outcome. Infra renal aortic conduit with stored donor iliac artery was used in one patient and a supra celiac aortic conduit was fashioned in the other because of postoperative thrombosis of a primary infra renal conduit. The third patient developed late HAT three months after transplantation resulting in anastomotic biliary stricture which was stented. He has no graft dysfunction over seven months follow-up. In the LDLT group, HAT occurred in two

Table 3 Recipient intra-operative parameters.

Parameters	DDLT	LDLT	P value
Operation time (min)	630	461	0.009*
Blood loss (mL)	2,950 (550–8,000)	2,415 (250–9,000)	NS
Blood transfusion (mL)	750 (0–3,850)	836 (0–3,500)	NS
FFP (mL)	1,695 (600–5,250)	1,530 (150–3,600)	NS
Platelets (mL)	222	250 (0–600)	NS
Cold ischaemia time (min)	263 (200–524)	116 (20–113)	<0.001*
Warm ischaemia time (min)	54 (36–71)	56 (35–94)	NS

DDLT: deceased donor liver transplantation, FFP: fresh-frozen plasma, LDLT: living donor liver transplantation, NS: not significant.

*P value significant.

Table 4 Complications in liver transplantation.

Complications <i>n</i> = 15 (28.3%)	DDLT <i>n</i> = 8 (22.8) (%)	LDLT <i>n</i> = 7 (38.8) (%)	Remarks
Hepatic artery thrombosis	3 (8.5)*	2 (11.1)	Two grafts revascularised surgically and endovascular stenting*
Portal vein thrombosis	–	2 (11.1)	Large spontaneous splenorenal shunts in one patient
Biliary leak	1 (2.8)	3 (16.6)	All managed by biliary stenting
Biliary stricture	2 (5.7)**	2 (11.1)	One patient retransplanted due to secondary biliary cirrhosis**
Pulmonary sepsis	3 (8.5)	3 (16.6)	
Acute rejection	4 (11.4)	–	
Delayed graft function	1 (2.8)	–	
Incisional hernia	1 (2.8)	–	
Diabetes mellitus	2 (5.7)	–	

DDLT: deceased donor liver transplantation, LDLT: living donor liver transplantation.

*Two grafts revascularised surgically and endovascular stenting, **one patient retransplanted due to secondary biliary cirrhosis.

Note: One patient had more than one complication.

paediatric recipients who succumbed due to graft failure in the immediate postoperative period.

Portal vein thrombosis occurred in two patients in the LDLT group. One adult developed PVT on the 10th postoperative day but did not show any evidence of graft dysfunction. Postoperative CT angiography revealed large spontaneous splenorenal shunt which was possibly responsible for the PVT. He has remained asymptomatic. The other patient aged six months with a reduced left lateral segment graft succumbed following PVT in the immediate postoperative period.

Biliary Complications

Bile leak occurred in four recipients (7.5%). All patients with bile leak were initially managed conservatively with external drainage for approximately two weeks to allow for spontaneous closure and healing of the biliary anastomosis. In persistent leaks which occurred in all our patients, endoscopic retrograde cholangiopancreatography (ERCP) and biliary stenting were carried out.

In the DDLT group one patient developed a bile leak. He had received an in situ split deceased donor liver graft. Biliary stent could not be placed due to a Roux-en-Y hepaticojejunostomy and absence of intrahepatic biliary dilatation.

He developed a biliary stricture and secondary biliary cirrhosis and was retransplanted with another deceased donor liver graft 2.5 years after the initial transplant. Anastomotic biliary stricture developed in another patient in the DDLT group following late HAT and he presented with cholangitis three months after the transplant. He was managed with ERCP and biliary stenting and in on regular follow-up.

In the LDLT group, three patients developed bile leak—one from the cut surface and two from the duct-to-duct biliary anastomosis. All bile leaks stopped following biliary stenting. The stents were removed after three months. However, both patients with anastomotic leaks developed biliary strictures. They were managed by biliary stents which are being changed every three months for larger stents or multiple stents and are on follow-up.

None of our patients with biliary strictures showed significant dilatation of the proximal biliary tree despite the anastomotic strictures. There was statistically no significant difference in the incidence of biliary leaks and biliary strictures between DDLT and LDLT in our series.

Transient renal dysfunction with raised creatinine occurred commonly in the recipients but all recovered spontaneously. This could be attributed to our immunosuppression policy of

Table 5 Mortality after liver transplantation.

Cause	DDLT <i>n</i> =5 (15.6%)	LDLT <i>n</i> =5 (27%)	Remarks
Primary nonfunction	2 (5.7%)	–	Grafts from elderly donors >75 years
Acute fibrinolysis	1 (2.8%)	–	Severe post reperfusion syndrome
HAT	–	2 (11.1%)	Occurred within seven days of surgery
PVT	–	1 (5.5%)	–
Recurrence of disease	1 (2.8%)	–	Widespread metastasis at three months from multifocal HCC detected in explant
Pulmonary sepsis	1 (2.8%)	2 (11.1%)	Both patients <1 year of age. Died one month and three months after transplant

DDLT: deceased donor liver transplantation, HAT: hepatic artery thrombosis, HCC: hepatocellular carcinoma, LDLT: living donor liver transplantation, PVT: portal vein thrombosis.

Table 6 Biliary complications in living donor liver transplantation.

Author	Year	<i>n</i>	Bile leak (%)	Biliary stricture (%)	Overall (%)
Gondolesi ²⁷	2004	96	21.9	22.9	40.6
Kling ²⁸	2004	48	20	17	33.3
Liu ²⁹	2004	41	7.3	24.3	24.3
Soejima ³⁰	2006	182	11.5	25.3	36.8
Soejima ³¹	2008	39	2.6	10.2	12.8
Marubashi ³²	2009	83	1.2	7.2	8.4
Kim ³³	2010	22	0	9.1	9.1
Soin ³⁴	2010	244	2	3.7	5.3

combining TAC and MMF so that TAC levels could be kept as low as possible to avoid such side effects. Persistent hyperglycaemia occurred in only two recipients.

The overall mortality was 18.8% (*n*=10). Three recipients died in the immediate postoperative period due to vascular complications. There was no mortality associated with biliary complications and there was no significant difference in mortality between DDLT and LDLT (*P*=0.09) (Table 5).

DISCUSSION

Orthotopic LT survival rates have significantly improved over the past few decades. This improvement is attributed to judicious pre-operative evaluation, excellent anaesthetic management, refined surgical techniques, aggressive nursing care, and prompt detection and treatment of complications. Survival rates and morbidity in our series are comparable with other international data. According to a United Network for Organ Sharing (UNOS) report, 1-, 3-, and 5-year survival rates after LT were 87.7%, 79.9%, and 74.3%, respectively. The cause of early mortality after liver transplant is mainly due to vascular complications, primary graft dysfunction and infection. Improvements in surgical techniques have made it possible for a single organ to be shared by two recipients. Split-liver transplantation (SLT) is now recognised as a practical and meaningful procedure to decrease waiting times among paediatric patients.¹⁹

Pre-existing PVT is not uncommon in patients with chronic liver disease undergoing transplantation with an incidence of 5–26%. Everson thrombectomy is adequate in most patients.^{20,21} It was seen in six (18.7%) of the patients in our series.

We have performed 13 DDLT using the standard caval replacement technique with caval clamping without using venovenous bypass. Venovenous bypass has the inherent risks of air embolism and vascular injury and with the availability of expert anaesthetic support its use is rarely indicated.²² Adequate hepatic venous outflow anastomosis is critical to prevent damage to the graft due to congestion. We always widen the outflow anastomosis by transverse cavotomy in the piggyback technique which was first described by Tzakis et al.²³

Vascular thrombosis after LT, particularly HAT, is a serious complication resulting in graft failure and death. The incidence of HAT has been reported to be 2–12%.²⁴ In India where donor organs are scarce, urgent revascularisation must be attempted in these patients. Urgent revascularisation was carried out in two patients in our series with excellent outcome. Meticulous technique is essential to prevent HAT. Several studies have recommended the use of operating microscope. However, it is more time consuming than the loupe approach and difficult to use within a deep abdominal cavity and associated respiratory movements.²⁵ We found the use of binocular loupes effective.

Biliary complications continue to be the major cause of morbidity in LT.²⁶ Many studies have shown a higher incidence of biliary tract complications in LDLT compared with DDLT. Ensuring integrity of the blood supply to the biliary tree, transecting the bile ducts along with the hilar plate and refinement in techniques of biliary anastomosis in LDLT has resulted in a significant reduction in the incidence of biliary complications from 24.3–40.6% before 2007 to 5.3–12.8% in studies published after 2008 (Table 6).^{27–34} Overall biliary complications in LDLT in our series was seen in three recipients (16.6%) which compares well with other studies. Aberrant biliary anatomy or two or more ducts have been proved to be a significant risk factor for the development of biliary complications. Only study from India involving 244 recipients has shown an incidence of 5.3% of biliary complications following LDLT.³⁴

CONCLUSION

Survival rates as well as the morbidity rates in our series are comparable with other international data. All attempts must be made to salvage grafts following HAT by urgent revascularisation. Refinement in techniques has reduced complications after LT. However, biliary complications remain the Achilles heel in LT especially in LDLT and result in long-term morbidity and mortality. However, in well-equipped centres where adequate expertise is available there is a significant reduction in the biliary complications in LDLT in the last few years.

Intellectual Contributions of Authors

Study concept: Brig Anupam Saha

Drafting and manuscript revision: Brig Anupam Saha, Surg Capt CS Naidu, VSM, Brig GS Ramesh, Surg Capt Joy Chatterjee, Col Pankaj Puri, Gp Capt Bhaskar Nandi, Lt Col Pradhi Nambiar, Wg Cdr Renu Madan

Statistical analysis: Brig Anupam Saha, Surg Capt CS Naidu, VSM, Brig GS Ramesh, Surg Capt Joy Chatterjee, Col Pankaj Puri, Gp Capt Bhaskar Nandi, Lt Col Pradhi Nambiar, Wg Cdr Renu Madan

Study supervision: Brig Anupam Saha, Surg Capt CS Naidu, VSM, Brig GS Ramesh, Surg Capt Joy Chatterjee, Col Pankaj Puri, Gp Capt Bhaskar Nandi, Lt Col Pradhi Nambiar, Wg Cdr Renu Madan

CONFLICTS OF INTEREST

None identified.

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Journal scan

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Road traffic injuries constitute a major public health problem in Spain. In recent years, the Spanish government has implemented several measures to reduce the burden of traffic injuries. Despite existing laws, the number of injuries and deaths attributable to speeding and drunk driving was still extremely high. To further reduce road injuries linked to these behaviours, the penal code was modified on 1st December 2007 in which several traffic offences were criminalised. The main criminalised offences were driving over the speed limit, drunk driving, reckless driving, and driving without a license. There is novelty in this study because it fills gap by examining the effect of criminalising several road behaviours on the numbers of drivers involved in injury collisions and of people injured in traffic collisions in Spain. Investigators used interrupted time-series design to conduct an evaluation study in drivers involved in traffic collisions and the number of people injured in traffic collisions in Spain in 2000–2009. Data was collected from Road Traffic Crashes Database of Spain's General Traffic Directorate. Time-series analysis was done by Poisson regression models, controlled for time trend, seasonality, fuel consumption and previous road safety interventions to account for changes in potential confounders, such as improvements in vehicle safety or in road behaviour, throughout the study period.

To control for changes in exposure, we adjusted for national fuel consumption in the models. It was found that there was clear reduction in the number of male drivers involved in injury collisions compared with the expected numbers; notably, no such reduction was observed among female drivers. The largest reductions in risk were observed for seriously injured and fatally injured drivers, all ages <65 years, non-urban roads and during both day and night time. Greater reductions were observed among young male drivers, especially those riding motorcycles and mopeds may be, at least to some extent, because men and young drivers tend to engage in the riskier behaviours that were criminalised by the reformed penal code and to the fact that riders of powered two-wheel vehicles, especially mopeds, tend to be less compliant with road safety legislation. Large sample size allowed authors to stratify the analysis by relevant variables such as age, sex, type of road user, road type, and time of collision and the long pre-intervention period provided analytical stability. However, they were unable to separately analyse the effect of each of the road behaviours penalised. The results of the study suggest that criminalising certain road traffic behaviours can effectively improve road safety by reducing both the number of drivers involved in injury collisions and the number of people injured in traffic collisions. These findings can probably be generalised to other countries that have efficient road traffic administration and that prioritize traffic law enforcement.

Contributed by
Mahesh S Hoolageri*

*Resident, Department of Community Medicine,
AFMC, Pune – 40.

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