

Cost of Trauma Care in Secondary- and Tertiary-Care Public Sector Hospitals in North India

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Abstract

Background Several initiatives to provide trauma care, including ambulance services, creation of a network of trauma hospitals and insurance schemes for cashless treatment, are currently being implemented in India. However, lack of information on the cost of trauma care is an impediment to the evidence-based planning for such initiatives. In this study, we aim to bridge this gap in evidence by estimating the unit cost of an outpatient consultation, inpatient bed-day of hospitalization, surgical procedure and diagnostics for providing trauma care through secondary- and tertiary-level hospitals in India.

Methods We undertook an economic costing of trauma care in a secondary-care district hospital and a tertiary-level teaching and research hospital in North India. Cost analysis was undertaken using a health system perspective, employing a bottom-up costing methodology. Data on all resources—capital or recurrent—on delivery of trauma care during the period of April 2014 to March 2015 were collected. Standardized unit costs were estimated after adjusting for bed occupancy rates. Sensitivity analysis was performed to account for the uncertainties due to differences in prices and other assumptions.

Results The cost of trauma care in the tertiary care hospital was INR 9585 (US\$147.4) per day-care consultation; INR 2470 (US\$37.7) per bed-day hospitalization (excluding ICU), INR 12,905 (US\$198.5) per bed day in ICU and INR 21,499 (US\$330.8) per surgery. Similarly, in the secondary-care hospital, the cost of trauma care was INR 482 (US\$7.4) per outpatient consultation, INR 791 (US\$12.2) per bed day of hospitalization, INR 186 (US\$2.9) per minor surgery and INR 6505 (US\$100.1) per major surgery.

Conclusion The estimates generated can be used for planning and managing trauma care services in India. The findings may also be used for undertaking future research in estimating the cost effectiveness of trauma care services or models of care.

Key Points for Decision Makers

Our study provides estimates on cost of secondary- and tertiary-level trauma care in India. At the overall level, provision of hospitalized trauma care costs INR 2470 (US\$37.7) and INR 791 (US\$12.2) per bed day in tertiary-care and secondary-care hospitals, respectively. Similarly surgical care costs INR 21,499 (US\$330.8) per surgery in a tertiary hospital, and INR 6505 (US\$100.1) per surgery in a secondary hospital.

The estimates on cost of trauma care could be used by policy makers for planning trauma care services, purchasing trauma care, and to evaluate cost-effectiveness of different trauma care services and platforms of care.

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1 Introduction

Globally injuries account for 5.1 million deaths per year, 9.2% of mortality. The impact is particularly high in productive age groups with 47% of injury-related deaths occurring among those aged from 15–49 years [1]. In India, trauma due to road injury is the seventh leading cause of mortality [2]. The economic cost of road traffic crashes globally has been estimated at US\$518 billion. In India, road traffic injuries cost US\$20 billion per year, which is 3.2% of the gross domestic product (GDP) [3].

Several interventions from both a supply- and demand-side perspective have been implemented in India to improve access to curative care for trauma cases. From the supply point of view, several trauma centres have been created across the country, primarily based in and around major cities [4]. From the demand-side perspective, benefit packages of several publicly financed health insurance schemes in India have incorporated trauma care in their coverage. More than 300 million people below the poverty line and those working in the informal sector in India are part of such schemes [5]. Schemes that specifically target road traffic injury victims are also being implemented—for example, the Ministry of Road Transport and Highways implemented the National Highway Accident Relief Service Scheme [6]. This scheme includes a cashless insurance cover of Indian Rupees (INR) 30,000 and treatment during first 48 h following the crash, including an ambulance service for quick referral from point of injury. Besides these, other notable interventions to strengthen trauma care include recognition of Emergency Medicine as a distinct specialty by the Medical Council of India in 2009, development of injury surveillance and trauma registries, and establishing ambulance networks along with standard operating protocols to improve pre-hospital trauma care [2].

Planning and management of these programs requires evidence of cost of trauma care, which helps healthcare managers to allocate resources to facilities and services, introduce or set user fees, assess the comparative efficiency of healthcare services and determine budgets to run health services. Similarly, evidence of hospital costs is important for establishing provider payment rates in social security schemes. However, there are significant gaps in evidence of the cost of trauma care from low and middle income country settings [7]. Several studies in India have reported the cost of trauma care from a patient's perspective [8–12]. However, there is a dearth of robust evidence on the economic implications from the service provider or health system's perspective. Furthermore, among those studies that estimated the health system costs, most had gross limitations in terms of lack of access to robust price data

for some equipment and instruments, non-accountability of donated items in the cost calculation, or a non-representative sample of study hospitals [13–15]. Similarly, depreciation of assets and the consumption of capital costs were ignored in earlier studies [16, 17]. With the aim of addressing the gap in evidence, we undertook this study to estimate the unit cost of an outpatient consultation, inpatient bed-day of hospitalization, surgical procedure and diagnostics for providing trauma care through the secondary- and tertiary-level hospital.

2 Methodology

2.1 Study Setting

The study was undertaken at a large tertiary-care teaching hospital (henceforth referred to as TH) and a secondary-care level hospital district hospital (henceforth referred as DH). The choice of these two hospitals was purposeful, as they catered to large volumes of trauma patients. Additionally, Panchkula district hospital was chosen for assessment of cost of secondary care, as the infrastructure and service availability in this DH was closest to the quality guidelines specified under Indian Public Health Standards (IPHS) [18]. The reason for choosing a hospital which represented close to IPHS standards was to ensure that the cost represents the setting which invests adequately in terms of infrastructure and resources for provision of trauma care.

2.1.1 Trauma Centre, Tertiary Hospital (TH)

The TH is a large 1850 bedded super specialty institute. Advanced Trauma Centre (ATC) of TH is a specialized and fully equipped centre catering to the needs of trauma victims. Injury patients reach TH directly or are referred from other hospitals. A total of 13,656 trauma patients received care in TH during 2014–15.

The Outpatient Department (OPD) in TH is atypical and provides day-care rather than typical OPD consultation. In a typical OPD, patients are provided doctor or nurse consultation and sent back with a prescription. However, in the study TH, considering the nature of medical condition—i.e. trauma—patients were kept under observation till their condition stabilized. The average length of such a stay in the OPD was 1.8 day. If the patient requires further hospitalized care s/he is shifted to the Inpatient Department (IPD) wards of the trauma centre. This difference from a typical outpatient setting is important to recognize as it has implications for resource use, and hence its cost. The IPD has general wards and specialized wards including surgical

ward I (general plastic surgery ward, plastic surgery ward for burn patients, ENT and dental ward), surgical ward II (general surgery, neurosurgery and plastic surgery ward) and an intensive care unit. Besides this, other services include surgery in the operating theatre (OT) and diagnostics services for a range of necessary radiological and laboratory tests. The majority of ATC patients receive care in the orthopaedic department (46%) followed by neurosurgery (29%), plastic surgery (12%) and general surgery (6%) departments.

2.1.2 Trauma Centre, District Hospital (DH)

DH is a 300-bed secondary-care district level hospital located in the district of Haryana state. There are 20 beds in the emergency department. Trauma patients are treated along with other emergency patients at the emergency centre of the hospital. Severe trauma patients are referred to TH or other tertiary-care hospitals in the region. A total of 11,511 trauma patients received care at DH during 2014–15.

2.2 Study Design

Costing was undertaken from a health systems perspective using bottom-up costing methods [19]. A health system perspective implies that all costs incurred by the health system for provision of services were accounted for, while any out-of-pocket expenditure was not included. As part of bottom-up economic costing, all resources which were used for provision of care were identified, measured and valued. Those resources that were used and not paid for by the health system, i.e. donated goods, volunteer time, etc. were also considered and valued. Cost-centre classification and organizational analysis was done. The area within the trauma centre was divided into primary-care cost centres (PCCs) and secondary-care cost centres (SCCs). PCCs comprised direct and indirect care centres. Direct care centres include three major departments including operating theatres with recovery wards, and an inpatient and outpatient department. The inpatient department includes a general ward, orthopaedic unit (surgery ward I), neurosurgery unit (surgery ward II) and intensive care unit. Indirect care centres include a radiology department and laboratory. SCC includes administration, laundry, dietetics, water, electricity, security, transport, blood bank, maintenance, store and other units. The types of resources consumed and services rendered at each of these were identified and measured.

2.3 Data Collection

Annual data on resources consumed for provision of trauma care were collected from April 2014 to March

2015, to encompass all the seasonal variations. Complete information regarding buildings and space was collected from hospital-engineering departments. Data on outpatient consultation and inpatient bed days were obtained from medical records and reports, and number of surgeries was collected from operation theatre register. Laboratory, radiological and other diagnostic tests were collected from their respective individual departments. For capital costs including medical and non-medical equipment, data on price and year of purchase were obtained from the procurement branch of the hospital. Quantities of drugs, consumables and non-consumables used for trauma patient care were obtained from stock registers of the respective cost centres. Data on staff salaries, drugs and consumables prices, and other expenditure (if any) were collected from hospital administration records. Sources of data are described in Table 1.

Staffs were interviewed regarding their time allocation for various activities. In ATC of TH, two resident doctors, two staff nurses and two non-medical staff were interviewed from each of the cost centres. Pretested questionnaires used in previous Indian studies were adapted [20] and used for the present study. Reported time allocation was triangulated by personal observation, and review of call book and duty rosters.

Donated items such as equipment, drugs/consumables and unpaid trainee/students were also considered in the study. Cost of trainees/students was determined by using the 'shadow price' [19] for such persons. Shadow price is an opportunity cost of an activity or resource, computed where actual price is not known or, if known, does not reflect the real price made. Shadow price for these trainees was taken as being equivalent to the salary for trained professionals employed in the same cost centre doing the same work as performed by these trainees. Data on average life of the equipment were collected by interviewing the technical officer-in-charge of the unit. Apart from expert elicitation, literature was reviewed to cross validate for the life of capital items [11, 20, 21].

2.4 Data Analysis

For the building or space costs, rental price was multiplied by the floor area to estimate opportunity cost of building being used [19]. Annualized cost of the other capital resources was estimated considering the life of the item and a discount rate of 5% [11, 20, 21]. For resources that were used for trauma care alone, the entire cost of the item was considered for the same. In case of joint or shared costs, either capital or recurrent, the cost of the overall resource that was used for trauma care was apportioned using suitable statistics. For example, recurrent costs of human resource costs were apportioned based on the time allocated in each cost centre.

Table 1 Sources of data and apportioning statistics for cost of trauma care type of data

	Source of data	Form of data	Method used to annualize/estimate annual cost	Allocation criteria
Capital items				
Building/apace	Record review (maps), facility observation	Maps	Estimated the floor size of constructed area multiplied with local commercial rental price	Record taken from civil engineering department of TH and shared areas apportioned on the basis of number of patients
Equipment	Record review (stock register), facility observation	Stock registers	Annualization factor multiplied with purchase price plus annual maintenance cost	Equipment costs were designated to particular cost centre
Recurrent items				
Human resource	Record review, Interview, Facility observation	Pay slips, on-call books	Salary multiplied with the proportion of time spent in a year on trauma care services	Most of the human resources were providing full time of their duty to trauma care except consultants and on-call doctors for whom apportioning was done on the basis of time allocated to trauma care
Medicines and consumables	Record review	Stock register	Annual amount of drugs/consumables and price data	Amount of medicines and consumables was taken separately for each of the cost centres
Other consumables (stationary)	Record review	Stock register	Annual amount of consumables and price data	Amount of other consumables was taken separately for each of the cost centres
Overheads				
Electricity	Record review	Monthly electricity bills (TH)	Annual consumption of electricity in ATC (TH)	Apportioning was done on the basis of floor area of trauma centre
Water	Record review	Account book (DH) Monthly water bills (TH)	Annual amount spent on consumption (DH) Annual consumption of water in ATC (TH)	Apportioning was done on the basis of floor area of trauma centre
Annual maintenance (overall)	Record review	Account book (DH) Stock register (TH) Account book (DH)	Annual amount spent on consumption (DH) Annual amount spent on consumption	Apportioning was done on the basis of floor area of trauma centre.
Laundry	Record review	Stock register (TH) Account book (DH)	Annual volume of linen (TH) Annual amount spent on consumption (DH)	Amount of laundry items was taken separately for each of the cost centres
Sanitation	Record review	Stock register (TH) Account book (DH)	Annual amount spent on consumption	Amount of sanitary items was taken separately for each of the cost centres
Dietetics	Record review	Stock register (TH) Account book (DH)	Annual volume of diets (TH) Annual amount spent on consumption	Amount of diets consumed was taken separately for each of the cost centres

As in DH, the trauma centre functions as a part of 24×7 emergencies; therefore all the recurrent, capital and overhead costs were apportioned from emergency to trauma based on number of patients. Electricity, water, annual maintenance and sanitation costs for emergency centre were apportioned from whole of DH to trauma based on floor area. Laundry and diet costs were apportioned on the basis of number of patients

TH teaching hospital, DH district hospital

Details of appropriate statistics for analysing shared or joint costs are given in Table 1.

All the costs were converted to US\$ for comparability at global level at the rate of US\$1 = INR 65 [22]. The unit cost of trauma care was estimated per outpatient consultation, inpatient bed day, per surgery, radiological investigations and laboratory investigations. Specific unit costs were computed by dividing the total annual cost incurred for a particular activity, for example, outpatient care, by the total number of outpatient consultation. In case of unit costs for hospitalization, while numerator was the total cost of providing hospitalized inpatient care, the denominator was inpatient-bed days which is a product of the number of patients hospitalized and the average length of stay. These unit costs can be influenced by the extent of utilization of a health facility—a facility with a high footfall of patients will have a lower unit cost of outpatient consultation, given the same level of fixed resources. Hence, standardised estimates for unit cost were also calculated for a bed occupancy rate of 100%.

2.4.1 Sensitivity Analysis

Univariate sensitivity analysis was undertaken to evaluate the influence of parameter uncertainties on total costs. Salaries for human resources, prices of drugs and equipment, and rental costs were varied by 25, 100, 25 and 25% on either side of the base value. Methodological uncertainties for estimating building/space costs were examined using a scenario analysis. In the first approach or base-case rental cost data were used along with the area being used for service to estimate building and land cost. In the scenario analysis, we used data on construction costs of building that were obtained from a civil engineering department. Assuming the average life of building as 50 years and depreciating by 5% discount rate [11, 20, 21], we calculated the annualized cost of building and space. This was compared with the base-case cost of building, which was estimated by calculating the opportunity cost using rental price of space.

2.5 Ethical Considerations

The study was approved by the Institute Ethics Committee of the Post Graduate Institute of Medical Education and Research, Chandigarh, India. Written informed consent was obtained from participants prior to the interview for time allocation.

3 Results

3.1 Profile of Study Hospitals

The TH catered to a large number of trauma patients during 2014–15, with 6352 in the outpatient department and 7304

hospitalizations in the trauma-associated wards. The annual number of diagnostics comprising computerised tomographic (CT) scans, magnetic resonance imaging (MRI) scans, radiographs (X-ray films), ultrasonographies, haemograms, coagulograms, routine urine examinations and body fluids were 10,585, 2868, 32,463, 11,336, 134,635, 35,616, 3260 and 1704, respectively. Average length of stay (in days) for outpatient day care, general ward, unit I, unit II and ICU was 1.8, 8.14, 11.99, 8.8 and 10.33, respectively.

The annual number of patients in the trauma OPD and trauma IPD in DH was 10,392 and 1119, respectively. Of all the hospitalised patients, 673 (673/1119; 60%) were admitted to the orthopaedic ward for follow-up treatment; of these, 535 (535/673; 80%) underwent major surgery. The average length of stay was 17.8 days. A total of 1654 minor surgeries were performed during the study period.

3.2 Annual Costs

The annual cost incurred for trauma care in DH and TH hospitals was INR 19.6 million (US\$301,444) and INR 418 million (US\$6.4 million) respectively. The share of capital cost in total cost was 16 and 36% in DH and TH, respectively. Human resources accounted for 45% of the overall costs, while building/space costs and drugs and consumables accounted for 36 and 19%, respectively. A detailed breakdown of the annual cost of trauma care in tertiary- and secondary-care hospitals by the type of resources and cost centres is shown in Tables 2 and 3. Nearly half of the total costs for trauma care were on account of hospitalization in both the TH (49%) and DH (47%).

3.3 Unit Costs

The unit cost of providing trauma care in TH was INR 9585 (US\$147.4) per outpatient visit, INR 2470 (US\$37.7) per bed-day hospitalization (excluding ICU), INR 12,905 (US\$198.5) per bed day in ICU and INR 21,499 (US\$330.8) per surgery (Table 4). The unit costs per CT scan, MRI scan, ultrasonography and X-ray were INR 849 (US\$13.1), INR 3358 (US\$51.7), INR 230 (US\$3.5) and INR 406 (US\$6.7), respectively. Unit costs per constituent of haemogram, coagulogram, routine urine examination and body fluid examination were INR 4.6 (US\$0.07), INR 20.7 (US\$0.32), INR 8.5 (US\$0.13) and INR 10 (US\$0.15), respectively.

Cost of trauma care in the DH was INR 482 (US\$7.4) per outpatient consultation, INR 791 (US\$12.2) per bed day hospitalization, INR 186 (US\$2.9) per minor surgery and INR 6505 (US\$100.1) per major surgery (Table 5). The standardized unit cost of trauma care services in secondary- and tertiary-care hospitals, shown in Table 5, are based on a 100% occupancy rate.

Table 2 Cost of trauma care in a tertiary-care hospital by type of resources and cost centres, 2014–15

Cost head	Cost in INR (US\$)									
	Intensive care unit	Operation theatre	General ward	Unit I surgical ward	Unit II surgical ward	Outpatient department	Recovery	Radiology	Laboratory	Total
Capital items										
Building/space	12,354,767 (190,073)	37,887,580 (582,886)	10,239,813 (157,536)	22,369,821 (344,151)	32,795,631 (504,548)	13,669,902 (210,306)	4,088,871 (62,906)	1,596,274 (24,558)	147,395 (2268)	135,150,053 (2,079,232)
Equipment	1,917,016 (29,493)	2,879,247 (44,296)	336,794 (5181)	717,850 (11,044)	443,249 (6819)	357,464 (5499)	314,563 (4839)	7,867,916 (12,045)	58,351 (898)	14,892,452 (229,115)
Total capital	14,271,784 (219,566)	40,766,828 (627,182)	10,576,607 (162,717)	23,087,671 (355,195)	33,238,879 (511,367)	14,027,367 (215,806)	4,403,434 (67,745)	9,464,190 (145,603)	205,745 (3165)	150,042,505 (2,308,346)
Recurrent items										
Human resources	27,385,122 (421,310)	44,941,643 (691,410)	20,643,464 (317,592)	19,121,080 (294,170)	20,493,332 (315,282)	34,812,782 (535,581)	11,539,359 (177,529)	7,685,472 (118,238)	463,290 (7128)	187,085,543 (2,878,239)
Medicines and consumables	2,224,331 (34,220)	8,038,784 (123,674)	1,844,893 (28,383)	2,549,737 (39,227)	2,868,227 (44,127)	6,807,339 (104,728)	1,031,871 (15,875)	6,389,773 (98,304)	721,796 (11,105)	32,476,752 (499,642)
Stationary	38,487 (592)	9,777 (150)	175,181 (2695)	114,765 (1766)	174,299 (2682)	303,829 (4674)	124,273 (1912)	97,687 (1503)	1099 (17)	1,039,397 (15,991)
Overheads	3,139,862 (48,306)	9,670,402 (148,775)	5,637,614 (86,733)	6,610,600 (101,702)	10,362,435 (159,422)	4,931,584 (75,871)	3,715,878 (57,167)	3,715,878 (57,167)	18,637 (287)	47,802,888 (735,429)
Total recurrent	32,787,802 (504,428)	62,660,605 (964,009)	28,301,153 (435,402)	28,396,182 (436,864)	33,898,294 (521,512)	46,855,534 (720,854)	16,411,380 (252,483)	17,888,809 (275,212)	1,204,822 (18,536)	268,404,580 (4,129,301)
Total	47,059,586 (723,994)	103,427,432 (159,1191)	38,877,760 (598,119)	51,483,853 (792,059)	67,137,173 (1,032,880)	60,882,900 (936,660)	20,814,814 (3,202,880)	27,352,998 (420,815)	1,410,567 (21,701)	418,447,085 (6,437,647)

Table 3 Cost of trauma care in district hospital by type of resources and cost centres, 2014–15

Resource type	Outpatient consultation, INR (US\$)	Hospitalization, INR (US\$)	Minor operative procedures, INR (US\$)	Major operative procedures, INR (US\$)	Total, INR (US\$)
Building/space	378,057 (5816)	1,693,528 (26,054)	519,354 (7990)	160,642 (2471)	27,515,81 (42,332)
Equipment	1,041 (16)	186,285 (2866)	5551 (85)	189,058 (2909)	3,819,35 (5856)
Human resources	950,298 (14,620)	3,113,916 (47,906)	220,491 (3392)	1,698,602 (26,132)	59,833,07 (92,501)
Diagnostics ^a	3,222,265 (49,573)	1,603,989 (24,677)	–	–	48,262,54 (74,250)
Drugs and consumables	325,920 (5014)	713,505 (10,977)	1,061,861 (16,336)	586,571 (9024)	26,878,57 (41,352)
Other consumables (stationary)	10,595 (163)	69,027 (1062)	3532 (54)	29,971 (461)	1,131,25 (1740)
Overheads	124,930 (1922)	1,786,390 (27,483)	124,930 (1922)	813,550 (12,516)	28,498,00 (43,843)
Total	5,013,106 (77,125)	9,166,640 (141,025)	1,935,719 (29,780)	3,478,394 (53,514)	195,938,59 (301,444)

^a Diagnostics (inclusive of all HR, Consumables, Space)

Table 4 Unit cost of trauma care services in a tertiary-care hospital, 2014–15

Cost centres	Total cost, INR (US\$)	Output	Unit	Unit cost, INR (US\$)
Intensive care unit	47,059,586 (723,994)	353	Bed days	12,905 (198.5)
Operation theatre	103,427,432 (1,591,191)	5,779	Cases/surgeries	17,897 (275.3)
General ward	38,877,760 (598,119)	2,704	Bed days	1765 (27.2)
Unit I surgical ward	51,483,853 (792,059)	1,573	Bed days	2729 (42.0)
Unit II surgical ward	67,137,173 (1,032,880)	2,674	Bed days	2854 (43.9)
Outpatient department	60,882,900 (936,660)	6,352	Visits	9585 (147.4)
Recovery ward	20,814,814 (320,228)	5,779	Cases/surgeries	3602 (55.4)
Radiology department	77,890,967 (1,198,323)	127,866	Cases	494 (7.6)
CT scan	35,000,081 (538,463)	41,226	Cases	849 (13.1)
MRI	18,121,591 (278,794)	5,397	Cases	3358 (51.7)
Ultrasound	10,748,031 (165,354)	46,707	Cases	230 (3.5)
X-ray	14,021,264 (215,712)	34,536	Cases	406 (6.7)
Laboratory ^a	15,991,560 (246,024)	2,032,759	Cases	8.1 (0.1)
Haemogram	6,760,337 (104,005)	1,479,479	Cases	4.6 (.07)
Coagulogram	7,566,505 (116,408)	364,904	Cases	20.7 (.32)
Urine examination	1,253,901 (19,291)	147,374	Cases	8.5 (.13)
Body fluids	410,817 (6,320)	41,002	Cases	10.0 (.15)

^a Unit cost of per constituent of various diagnostics in the Emergency Laboratory

3.4 Sensitivity Analysis

Sensitivity analysis depicted that at tertiary level, total annual costs were most sensitive to a variation in human resource costs followed by building/space, overheads, and medicines and consumables (Fig. 1). At a secondary level, total cost was most sensitive to variation in human resource costs followed by cost of laboratory tests, overheads, building space costs, and medicine and consumables (Fig. 2).

We did a scenario analysis considering depreciated annualized construction cost of building in place of market rental price of equivalent space. With a change in

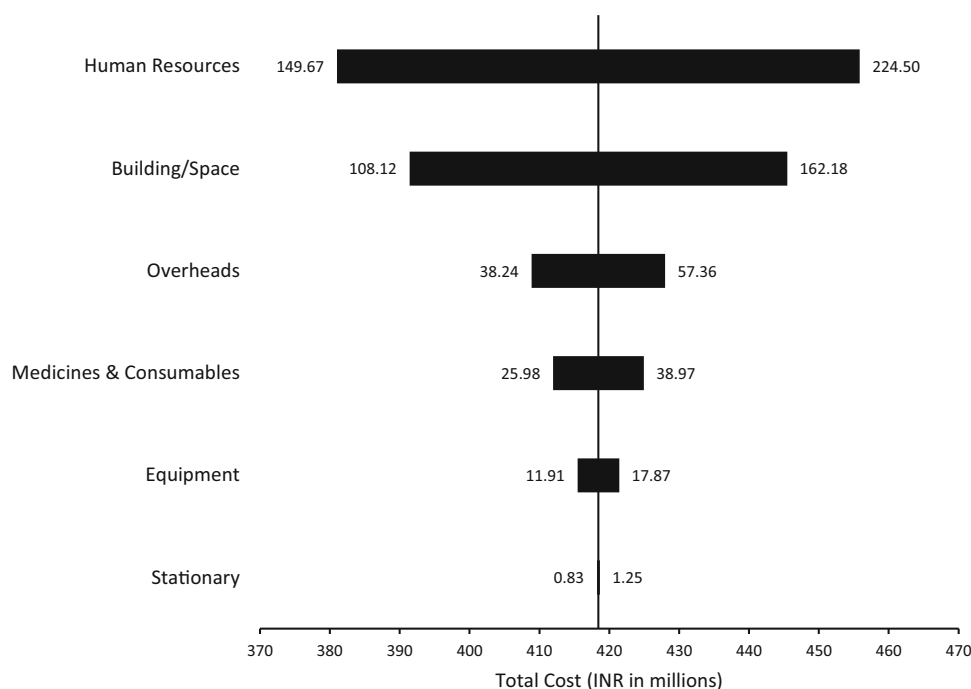
assumption, we observed a reduction of 19.4% in cost of providing trauma care in TH, and 8.4% reduction in cost at DH level.

4 Discussion

The burden of injuries as a cause of premature mortality in India has increased by 53% from 1990 to 2012 [1]. In order to address this challenge, India needs a national programme driving a multidisciplinary trauma care system. Over the years several trauma centres have been created across the country, mostly based in and around major cities [23]. The

Table 5 Summary unit costs of trauma care services in a secondary- and tertiary-care hospital, 2014–15

Cost centres	Unstandardized cost, INR (US\$)		Standardized cost, INR (US\$)		Unit
	Tertiary care	Secondary care	Tertiary care	Secondary care	
Outpatient consultation	9585 (147.4)	482 (7.4)	6750 (104)	349 (5)	Visits
Bed-day hospitalization except ICU	2450 (37.7)	791 (12.2)	1725 (27)	573 (9)	Bed days
Bed-day hospitalization in ICU	12,905 (198.5)	NA	15,140 (233)	NA	Bed days
Major surgery	21,499 (330.8)	6505 (100.1)	9088 (140)	4714 (73)	Cases/surgeries
Minor surgery	NA	186 (2.9)	NA	135 (2)	Cases/surgeries

Fig. 1 Tornado diagram showing the uncertainty in total annual cost for trauma care in a tertiary level hospital

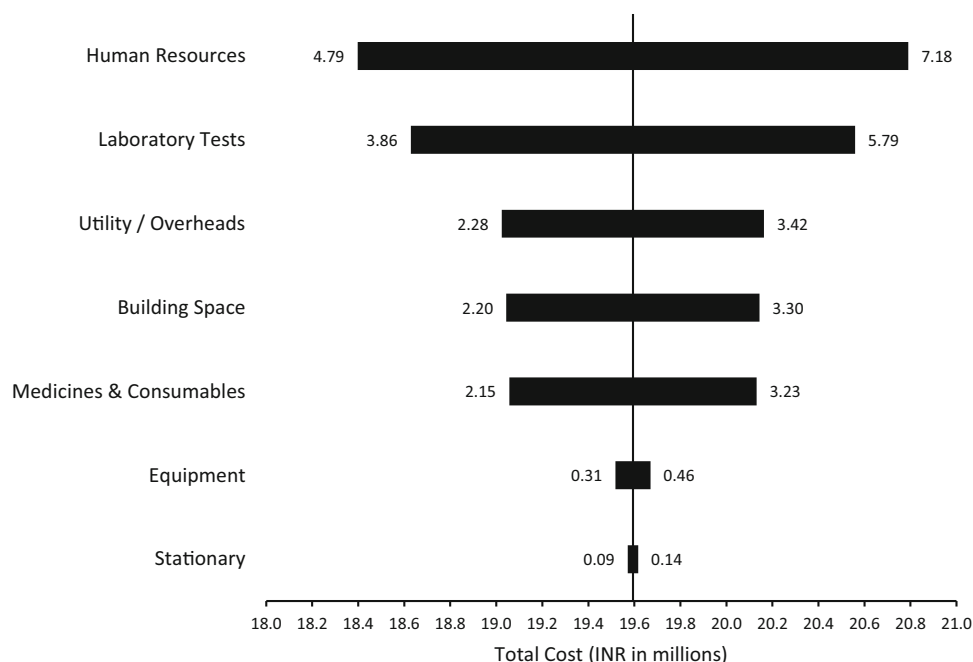
Government of India (GOI) has earmarked 140 locations along the Golden Quadrilateral Corridor, North-South and East-West Corridor for development of trauma care facilities for crash victims [24]. As part of this scheme, nearly 118 hospitals and medical colleges have been identified for strengthening trauma care facilities along national highways. Similarly, another 20 hospitals and medical colleges have been selected for building upgraded trauma centres under the *Prime Minister's Health Protection Scheme* (PMSSY) [24].

Despite this impetus on strengthening the public health delivery system for provision of trauma care, there is no study which focuses on the health system cost of trauma care. A couple of studies evaluate the cost of curative care including surgical and trauma care [13, 14]. There is relatively little known in public sector. Most of the existing studies have concentrated on estimating the out-of-pocket expenses incurred by individuals for availing various health services

[8–10, 12]. In our review, we found no study which specifically estimates the health system cost of providing trauma care services. In this light, our study is the first to estimate the cost of trauma care services, from a provider's perspective, at a secondary- and a tertiary-care hospital in India.

Overall, we found that the annual health system costs of providing trauma care through a secondary- and tertiary-care level hospital was INR 19.6 million (US\$301,444) and INR 418 million (US\$6.4 million), respectively. Salaries for human resources are the predominant cost (44%). Other studies have also reported similar findings [13, 14, 16]. This is also consistent with the findings of the working group on tertiary-care institutions in India, which showed that in most states, salaries and wages account for as much as 70% of the total health budget [25]. Several international studies on hospital costing also found that human resources constitute the majority of a hospital's total operating cost [15, 26–28].

Fig. 2 Tornado diagram showing the uncertainty in total annual cost for trauma care in a secondary level hospital



In terms of services, inpatient hospitalization cost contributes the bulk of trauma care cost in TH (49%) and DH (47%). Younis et al. reported an even higher contribution of inpatient costs (75%) to overall hospital costs [17]. This could possibly be because the latter study pools operative care costs with hospitalization costs. Pooling operative costs including both major and minor surgeries within the hospitalization costs inflates the share of latter in our study to 70 and 75% of total trauma care costs in TH and DH, respectively.

A recent study by Chatterjee et al. from India which covered a tertiary-care hospital reported the cost per patient treated in the OPD was INR 242, per bed day cost of hospitalization was INR 614 and unit cost of major surgery was INR 8362 [14]. Higher unit cost estimates in our study are due to our specific focus on trauma care services which requires more specialized and resource intensive care, while Chatterjee et al. reported the cost of all healthcare services. As per RSBY—India's flagship health insurance scheme—the government pays providers INR 1000–20,000 for ENT surgeries, INR 2000–29,750 for neurosurgeries and INR 2000–25,000 for orthopaedic surgeries [29]. These surgical rates are in concordance with the results of the present study.

Another study which covered five secondary hospitals in India reported that per bed-day treatment costs the government INR 818 (US\$18.2), which is close to the findings of our study [21].

Chatterjee and Laxminarayanan studied costs of surgical procedures in Indian hospitals from the provider perspective [13] and found that the costs of conducting amputation were INR 5158. This was comparable to the per unit major

surgery cost we found at the secondary-level hospital. However, unit cost of a major surgery at the tertiary-level hospital in our study was much higher than that estimated by these authors.

For diagnostic tests, we found the unit cost of a CT scan, MRI scan, ultrasound and X-ray to be INR 849 (US\$13.1), INR 3358 (US\$51.7), INR 230 (US\$3.5) and INR 406 (US\$6.7), respectively. These costs are lower than the provider payment rates in social security schemes like the Central Government Health Scheme (CGHS) [30] where the per unit CT scan, MRI, ultrasound and X-ray costs are INR 2400, INR 4500, INR 500 and INR 300–400, respectively. This shows that public sector hospitals are working in a reasonably cost-efficient manner. Secondly, it also suggests a need for revision of the rates of payment for providers in these health insurance schemes. Similarly, the costs of laboratory tests in our study were also found to be lower than the reimbursement rates of health insurance schemes like CGHS [30].

Interestingly the unit cost of radiography was approximately twice more than the ultrasonography test. This was on account of the higher operational cost of radiography than ultrasound. Running an X-ray unit involves more human as well as capital resources when compared to doing an ultrasound scan, besides using more consumables in the form of developers and fixers. Finally, the annual number of ultrasonographies performed was also 1.4 times higher compared to X-rays. All of these lead to a lower unit cost of ultrasonography.

We estimated the capital costs by using two different approaches. In the first approach capital cost is estimated

using rental price, which represents the opportunity cost of the building [19] while in the second approach capital cost was estimated on basis of depreciated value of construction costs, excluding land cost. By using the first approach, for TH it was seen that building/space contributed 32% of the share of the total cost whereas by using the second approach, building/space cost contributed only around 4%. This shows that by using different approaches or assumptions there is the possibility of obtaining significantly different results.

4.1 Strengths of Our Study

Firstly, ours is the first Indian study that focuses on the health system cost of trauma care. Most earlier studies on the cost of healthcare services in India have done so from a patient's perspective, reporting out-of-pocket expenditure. Few studies on the health system costs exist, and those that do tend to focus on general services without a specific focus on trauma care [20, 31, 32]. Secondly, in previous studies on costing, some common pitfalls were noted like lack of access to reliable price data for some equipment and instruments, donated items were not considered in the cost calculation, study hospitals were not representative, cost calculation was based on the average time taken for each procedure, which can differ from the actual time especially in critical cases, and depreciation of assets as well as the consumption of capital costs was ignored [13–17].

In our study we attempted to overcome the shortcomings of previous studies. We had selected the TH which is a public sector tertiary-level hospital catering as a referral centre for North India and a DH which is a public sector secondary-level hospital and is nearest in terms of meeting IPHS standards among 21 DHs in the state. These two hospitals can be considered as representative of tertiary- and secondary care provided in India. We used a comprehensive approach of economic costing rather than financial costing. Donated items, such as equipment or drugs, and opportunity costs of trainee/students were accounted for. Standardised cost estimates were also calculated on the basis of capacity utilisation, assuming bed occupancy rates to be 100%.

4.2 Limitations

We would like to note a few methodological and data limitations of our study. First, there was a lack of access to price data for some equipment and instruments in both the settings. However, these contributed less than 5% of total equipment. We used the market prices in such cases. Second, while the data on quantity of resources utilized

was available at the respective cost centre level for TH, the same was not the case for DH. Since the aggregate pooled data was available for resources at DH, apportioning factors had to be applied to assess the cost at each cost centre. This could lead to some inaccuracy in DH costs. Third, cost of ambulance for trauma patients could not be recorded in both the settings. Fourth, while administrative cost of trauma centre was included, the institute level administrative costs could not be recorded for the tertiary-care hospital. However, from previous other studies it was found that administrative costs account for less than 0.5% of total cost incurred in providing any healthcare service in the public sector [20, 21].

Fifth, due to the nature of records and data available in DH, detailed costing of laboratory services was not possible. Therefore the market price of the diagnostic test was used, which may be a slight overestimate. However, it was tested in the sensitivity analysis and was not found to have a major effect. Sixth, the quality of services could clearly explain some of the variations in costs, but it was beyond the scope of this study to estimate the quality of services being provided. Finally, it needs to be recognized that the estimates of unit cost are influenced by the patient mix being treated, in terms of the type and severity of injury. In an ideal scenario, the unit costs should be presented stratified by each type and severity level of injury. However, in Indian settings, recording injury severity is not a usual practice and hence the data were not available. Moreover, estimating costs by type of injury requires resource use at a pooled level, with any disaggregation by type of injury being treated. Future research studies in the area of injury economics should try to address this limitation of our study.

It may also be noted that the cost of provision of healthcare services vary significantly in different parts of country. This has been reported in health system costing studies done earlier in India [6, 20, 33–36]. These variations are the result of variation in human resource salaries, prices of drugs or consumables or equipment, and rental prices. Although we undertook a detailed sensitivity analysis to assess such uncertainties, it is recommended that future studies should include a larger more representative sample of health facilities so that the cost estimates are more generalizable.

5 Conclusion

The present study provides information on the economic cost of providing trauma care services in secondary- and tertiary-care public sector hospitals in India. These results can be used for policy purposes, such as setting or revising

the payment rates for provision of trauma care under various public sectors financed insurance schemes and reimbursement packages like the *Rashtriya Swasthya Bima Yojana* [29] or the Ministry of Road Transport and Highways Cashless Insurance Scheme for road traffic injury cases. These cost estimates can also be used for administrative purposes like planning and management of providing trauma care services or to improve the efficiency of hospitals. As we are moving towards universal health coverage, evidence on cost of various health services will be required so that we can rationalize our limited resources. Considering the gaps in existing coverage and high cost of care, any benefit package for universal health coverage would have to include trauma care. Recent assessments show gaps in provision of such curative care as well as inequities in access [37]. Finally, cost of trauma care, as found in our study, would be useful for undertaking future research to estimate the cost effectiveness of various trauma care services or models of care.

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Author Contributions SP and SA conceived the study; AS and SP designed the methods and tools; JJ and RI contributed to development of study methods; AS collected data; SP and SA supervised data collection; AS and PB analysed the data; AS wrote the first draft. All authors revised the manuscript and approved the final version.

Compliance with Ethical Standards

Conflict of interest No funding was received for this study. AS, SP, SA, JJ, PB and RI declare no conflicts of interest.

Glossary of Abbreviations

Abbreviation	Full form	Remarks
ATC	Advanced Trauma Centre	Centre for provision of specialized trauma care
CGHS	Central Government Health Scheme	Social health insurance scheme for Central Government Employees
CT	Computerized tomography	Radiological diagnostic test
DH	District Hospital	District-based secondary care hospital
ENT	Ear–Nose–Throat (Otolaryngology)	Surgical specialty in hospital
GOI	Government of India	

Abbreviation	Full form	Remarks
INR	Indian National Rupee	Indian currency
IPD	Inpatient Department	Hospital department providing care after admission, i.e. wards
IPHS	Indian Public Health Standards	Indian quality standards for health care facilities
MRI	Magnetic resonance imaging	Radiological diagnostic test
OPD	Outpatient Department	Hospital department providing outpatient consultations
OT	Operation theatre	Surgical care
PCC	Primary Cost Centre	Centre which is responsible for utilization of resources and providing direct patient care
PMSSY	Prime Minister's Health Protection Scheme	Central Government's scheme for strengthening tertiary-care facilities
RSBY	Rashtriya Swasthya Bima Yojana	India's national publicly financed health insurance scheme for below poverty line households
SCC	Secondary Cost Centre	Centre which is responsible for utilization of resources and providing supportive services
TH	Tertiary Hospital	Hospital providing specialized tertiary-care services
US\$	United States Dollar	US currency

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