Trinational Study Exploring the Early Impact of the COVID-19 Pandemic on Organ Donation and Liver Transplantation at National and Unit Levels

Mettu S. Reddy, PhD,[1] Abdul R. Hakeem, PhD,[1] Tarunjeet Klair, MD,[2] Francesca Marcon, MD,[3] Abhishek Mathur, MD,[4] Benjamin Samstein, MD,[5] Ravi Mohanka, MS,[6,7] Surendra K. Mathur, MS,[7] Andreas Prachalias, FRCS,[8] Krishna V. Menon, FRCS,[8] Paolo Muiesan, FRCS,[3] Mohamed Rela, DSc,[1] and Jean C. Emond, MD[4]

Background. The coronavirus disease (COVID-19) pandemic is stressing healthcare services to an unprecedented extent. There is anecdotal evidence of reduction in organ donation and transplantation activity across the world. **Methods.** The weekly organ donation and liver transplant numbers over a 3-month period (Feb 17, 2020, till May 17, 2020) for the United States, United Kingdom, and India were compared with their previous year's activity. Liver transplant activity in 6 centers from these countries with varying local COVID-19 caseload was also compared. **Results.** The COVID-19 pandemic has led to a significant contraction in organ donation and liver transplantation in all 3 countries. Peak reduction ranged from 25% in the United States to over 80% in the United Kingdom and India. The reduction was different for deceased donor and living donor liver transplantation and varied between centers within a country. There was early evidence of recovery of deceased donation in the United States and United Kingdom and resumption of living donor liver transplantation activity in India toward the end of the study period. A number of policy changes were undertaken at national and transplant center levels to ensure safe transplantation despite significant redirection of resources to combat the pandemic. **Conclusions.** There was a substantial reduction in organ donation and liver transplantation activity across the 3 countries with signs of recovery toward the end of the study period. Multiple factors including COVID-19 severity, stress on resources and influence of regulatory agencies and local factors are responsible for the reduction and recovery.

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INTRODUCTION

The coronavirus disease (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 is having a massive impact on all areas of clinical practice.[1] Many countries have seen a major shift in healthcare resources allocation to fight and control the consequences of this infection. In severely affected regions, elective clinical work has come to a standstill.[2,3] In other regions such as India, where the course of the pandemic has been slower, the anticipation of an influx of infected patients has led to a cautious reduction in elective work.

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[1] Liver Transplant Unit, Dr Rela Institute & Medical Center, Chennai, India.

[2] Liver Transplant Unit, University of Texas Health San Antonio, San Antonio, TX.

[3] Liver Transplant Unit, Queen Elizabeth Hospital, Birmingham, United Kingdom.

[4] Liver Transplant Unit, New York Presbyterian—Columbia University Medical Center, New York, NY.

[5] Liver Transplant Unit, New York Presbyterian—Weill Cornell Medical Center, New York, NY.

[6] Liver Transplant Unit, Global Hospitals, Mumbai, India.

[7] Zonal Transplant Coordination Center, Mumbai, India.

[8] Liver Transplant Unit, Kings College & Hospital, London, United Kingdom.

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Correspondence: Mettu S. Reddy, FRCS, PhD, Liver Transplant Unit, Dr Rela Institute & Medical Centre, 7 Works Road, Chromepet, Chennai 600044, Tamil Nadu, India. (smettu.reddy@gmail.com).

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There are reports of a sharp decrease in worldwide organ donation and transplantation (ODT) activity due to this pandemic.[4] Following early guidance from the Transplantation Society, a number of national and international organizations have provided general and region-specific advice to managing the fallout of the pandemic on ODT.[5-7] However, the actual extent of reduction and the impact of national interventions and the local COVID-19 situation on the transplant activity of a center is unclear.

MATERIALS AND METHODS

This is a joint report from 6 liver transplantation units based in the United States, United Kingdom, and India. The baseline characteristics of the 6 units are noted in Table 1. The period of study was from Feb 17 to May 17, 2020 (3 mo). The starting point of the study was chosen to coincide with the time when COVID cases were beginning to be identified in these countries. The World Health Organization declared COVID a pandemic of international concern on March 11, 2020, marking an important timepoint when targeted interventions to deal with its fallout should have been put in place.[8]

For the purpose of this report, national guidance provided to transplant centers in each country was reviewed and compared (Table 2).[9-11] For each country, the weekly deceased donation and liver transplantation activity data was collected for this 3-month period except for the United Kingdom where data from March 2, 2020, was available. The expected weekly activity was calculated by dividing the 2019 deceased donation and liver transplantation numbers by 52 (number of weeks in a year). Data were obtained from the United Network for Organ Sharing (UNOS) "COVID-19 and solid organ transplant" webpage for the United States, and the NHS Blood &Transplant "COVID-19: Advice for clinicians" webpage for the United Kingdom.[9-11] As a nationwide comprehensive transplant registry is not yet fully functional in India, organ donation and liver transplant activity data was obtained from transplant units and the regional bodies overseeing organ transplantation for the states of Tamil Nadu (Transplant Authority of Tamil Nadu, TRANSTAN)[12] and Maharashtra (Zonal Transplantation Coordination Centers at Mumbai, Pune, Nagpur). These 2 states have the highest deceased donation rates in the country and account for >50% of all deceased donations in India.

Center-specific data collected from the 6 transplant centers included liver transplantation performed during the study period, liver transplant canceled due to COVID-19-related issues, reallocation of intensive care unit (ICU) bed capacity, the impact of COVID-19 on transplant unit staffing, protocols of COVID-19 testing for patients and staff, and other changes in unit policies to deal with the pandemic. Descriptive methods were used for presenting data. Trends were compared between countries and centers and possible factors affecting ODT activity are discussed.

RESULTS

COVID-19 pandemic has affected over 5.7 million people with >357 000 deaths in 213 countries by May 30, 2020[1] (Figure 1). The characteristics of the 6 liver transplant units included in this study are summarized in Table 1. The current policy guidelines for organ donation and liver transplantation in these 3 countries are compared in Table 2.

United States of America

The United States currently has the highest number of infections with New York City as the epicenter of the pandemic.[1] There are reports of hospitals and ICUs inundated with COVID-19 patients with most elective clinical work coming to a standstill. Although many states have not imposed formal restriction on public movement, social distancing is being advised nationally. Given the large size of the country, there is significant variation in the local COVID-19 caseload and healthcare resource utilization across the country.[13]

UNOS has been regularly updating its COVID-19 guidance based on the changing severity of the pandemic.[11] The latest UNOS update has recommended local retrieval teams, preferential local allocation of organs and universal COVID testing for donors.

TABLE 1.

Baseline characteristics of the 6 liver transplant units included in the study

Participating unit	Location, local COVID-19 case load[a] (cases/1000 population)	Liver transplant volume (% DDLT) in 2019[b]	Peak reduction in % LT activity[c]
NYP and (Columbia University—Weil Cornell), New York City	New York, United States 18.98	149 (80%)	80%
UTHSA	Texas, United States 2.10	117 (66%)	60%
KCH	London, United Kingdom 3.06	255 (>90%)	80%
UHB	West Midlands, United Kingdom 2.96	243 (>90%)	80%
GHM	Maharashtra, India 0.56	78 (30%)	100%
RIMC	Tamil Nadu, India 0.28	225 (10%)	100%

[a]Region's COVID-19 cases per 1000 population was calculated from the number of confirmed COVID-19 cases as on May 30, 2020, in the state/region and the last official population count for that region.
[b]Liver transplant volume and %DDLT calculated from 2019 activity at each center.
[c]LT activity during 4 consecutive weeks in April and May 2020 with lowest liver transplantations performed as compared to 2019 activity.
DDLT, deceased donor liver transplantation; GHM, Global Hospital, Mumbai; KCH, Kings College & Hospital, London; LT, liver transplantation; NYP, New York Presbyterian; RIMC, Dr Rela Institute, Chennai; UHB, University Hospitals Birmingham; UTHSA, University of Texas Health San Antonio.

TABLE 2.

Differences and common themes in current national guidance regarding organ donation and liver transplantation in the context of the COVID-19 pandemic

	United States	United Kingdom	India
Deceased donation	To continue, encourage local recovery teams	To continue, phased increase in activity based on local situation	To resume, with restrictions on intercity movement
Living donor liver transplantation	To resume for selected cases	Phased reintroduction	Proceed for ALF, ACLF, and selected sick patients
COVID-19 testing for deceased donors	Mandatory, within 72 h of donation	Mandatory	Mandatory within 24 h of donation
Deceased donor with previous COVID-19 infection	If full recovery >28 d before donation and repeated negative COVID testing can be considered	If full recovery >28 d before donation can be considered	Do not proceed
COVID-19 testing for live donors	At least 1 test before surgery	Twice, at assessment and before surgery	Two tests before transplant. Consider testing patient carers.
COVID-19 testing for potential recipients	Recommended	Highly desirable	Recommended when prioritized on waiting list and at the time of liver offer
Perioperative transplant management	COVID-19 free clinical pathway Separation of recipients and living donors from potential COVID-positive patients during the perioperative period. Reduce in-hospital movement of patients during postoperative period.		
Immunosuppression	Standard. No preemptive modification for COVID		
Patient follow-up	Minimize routine hospital visits, use teleconsultations		

ACLF, acute on chronic liver failure; ALF, acute liver failure.

National ODT Activity

Reduction in national deceased donations was first evident in the third week of March (Figures 2 and 3; Figure S1, SDC, http://links.lww.com/TP/B988). Deceased donation and liver transplantation activity reduced by 25% in early April, before recovering substantially during the concluding weeks of the study period. Significant geographic variation in the extent of reduction has been noted with anecdotal reports of increased liver transplant activity in regions relatively spared from the COVID-19 crisis. There was a 75% reduction in living donor liver transplantation (LDLT) activity during this period although centers in the less affected regions have continued to perform LDLT for carefully selected cases.

Center-wise Activity

Liver transplant activity in both US centers reduced after the third week of March (Figure 4; Figure S2, SDC, http://links.lww.com/TP/B988). At New York Presbyterian,

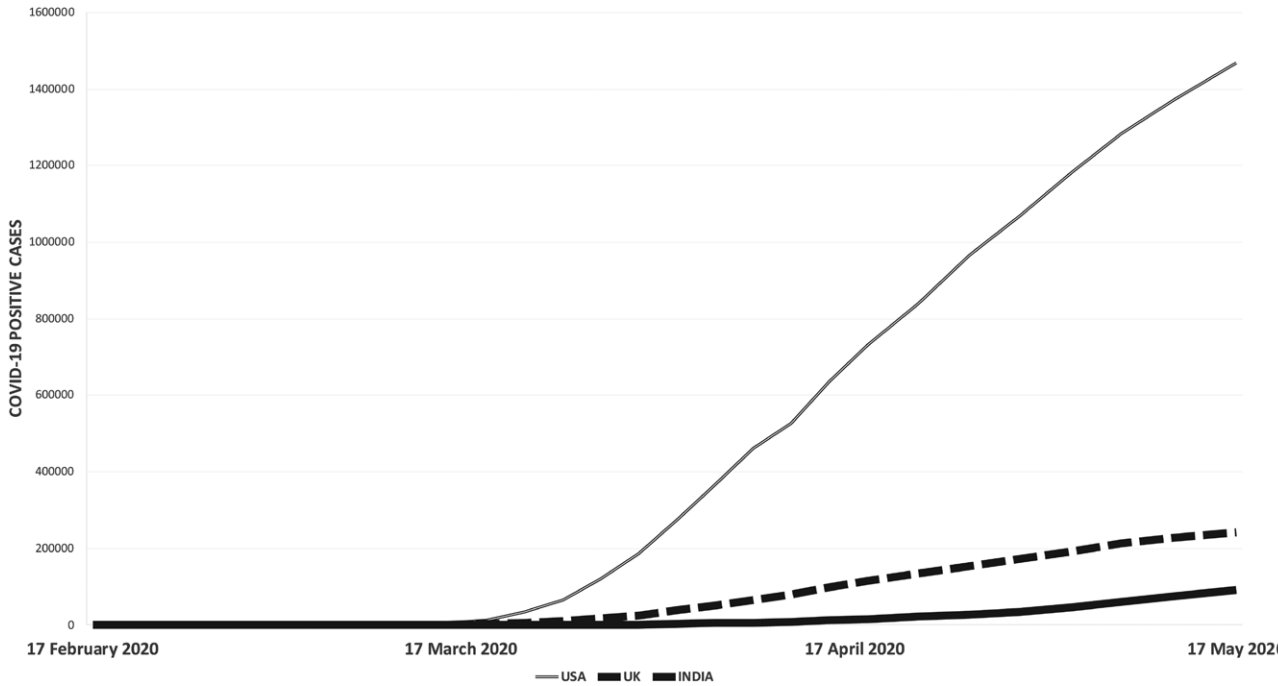

FIGURE 1. Number of proven COVID-19 infections in the United States, United Kingdom, and India during the study period. COVID-19, coronavirus disease.

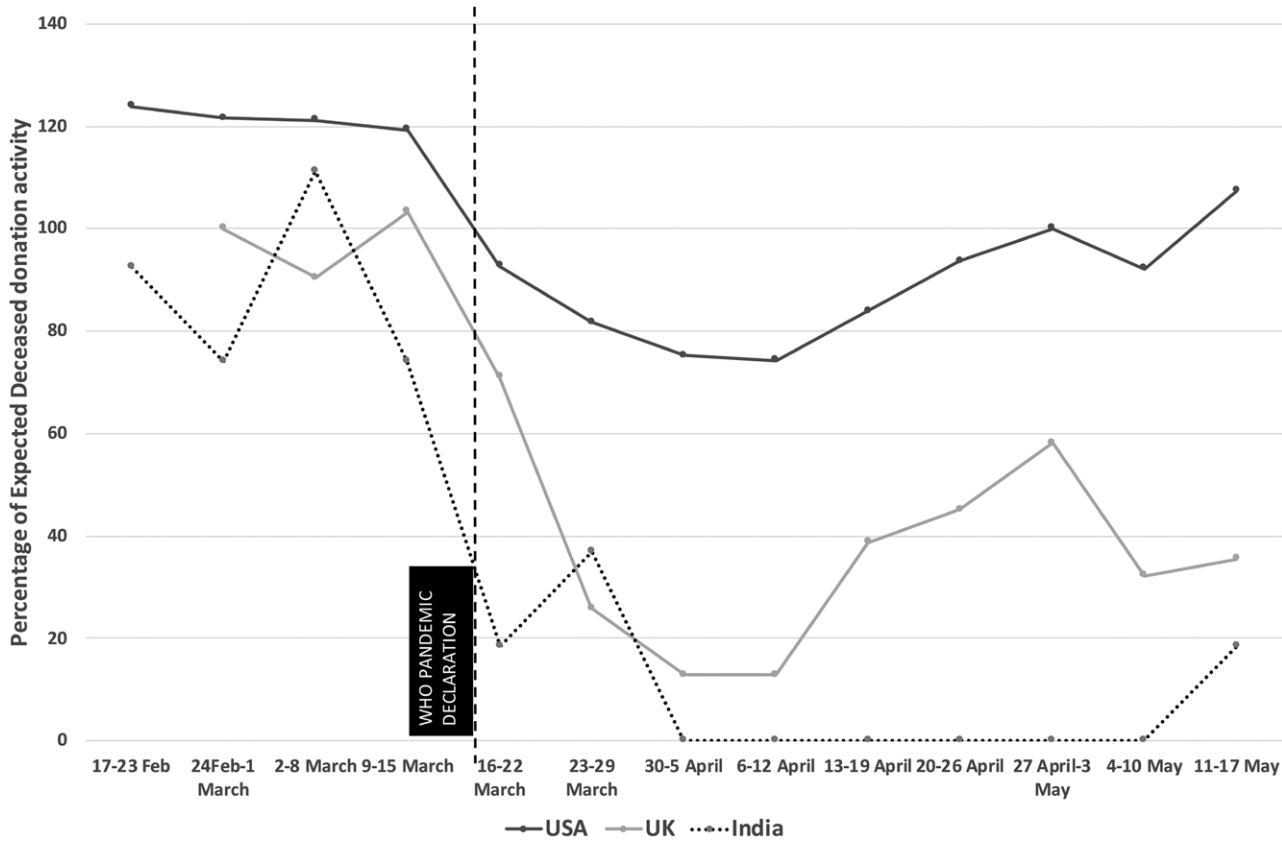

FIGURE 2. Comparative trends in deceased donor activity (as percentage of 2019 national activity) during the study period in the United States, United Kingdom, and India.

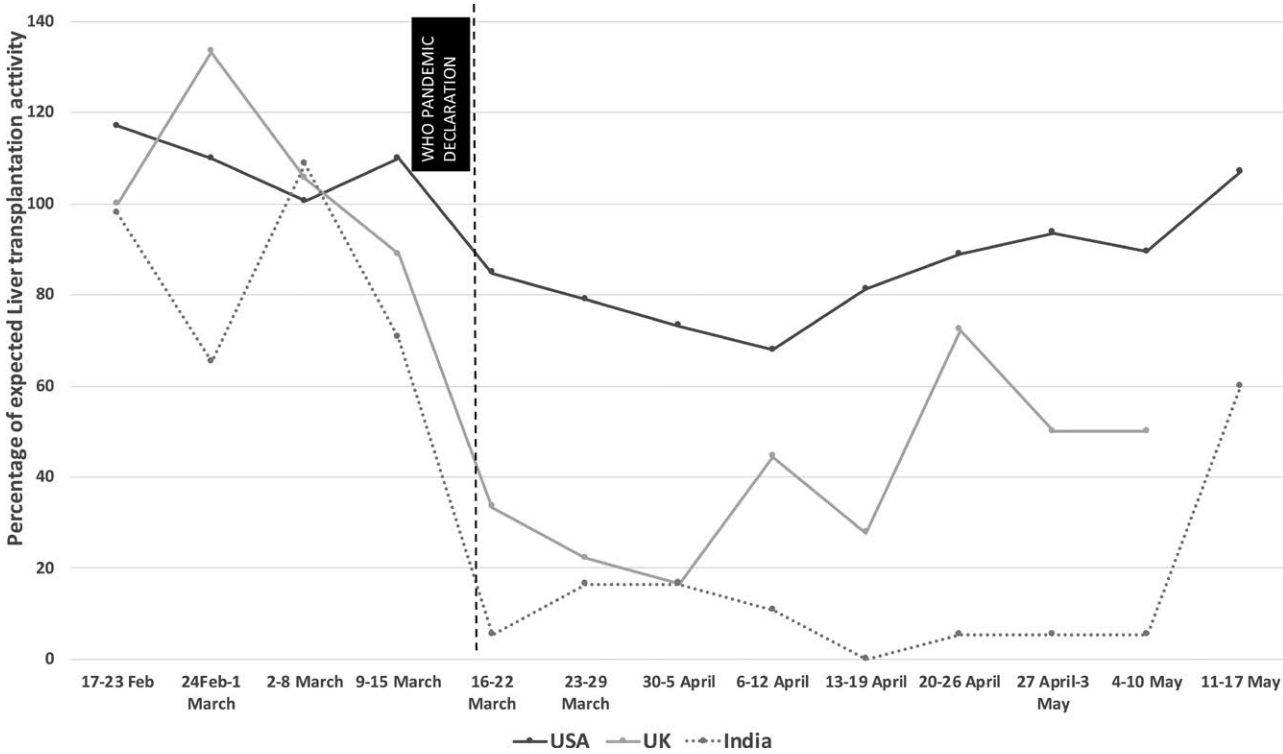

FIGURE 3. Comparative trends in liver transplantation activity (as percentage of 2019 national activity) during the study period in the United States, United Kingdom, and India.

this reduction in liver transplantation activity coincided with the exponential rise in COVID-19 cases in New York City and the subsequent sequestration of hospital resources and transplant staff to assist in COVID-19 patient care. Additionally, transplantation was also impacted by the reduction of deceased donor cases identified during this

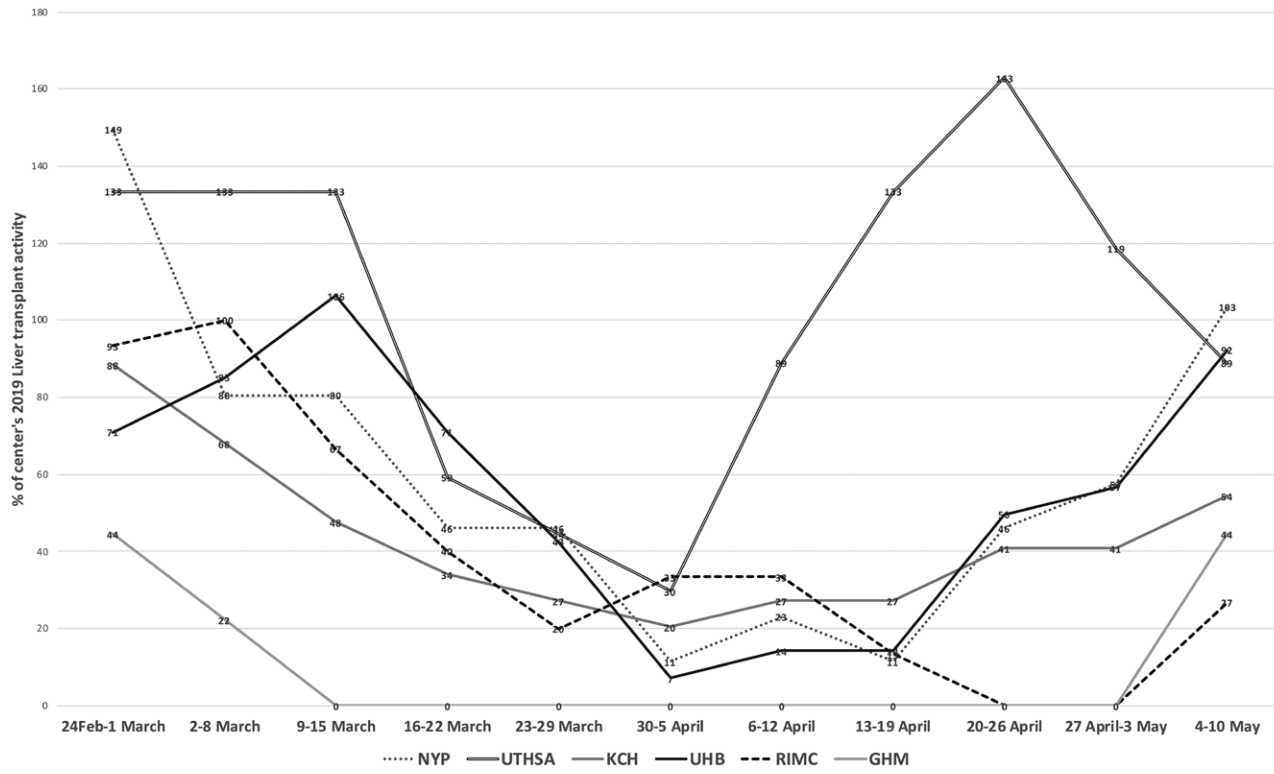

FIGURE 4. Comparative trends in the 3 wk moving average of liver transplantation activity of the 6 centers during the study period (as percentage of 2019 activity). GHM, Global Hospitals, Mumbai, India; KCH, Kings College & Hospital, London, United Kingdom; NYPH, New York Presbyterian Hospital, New York City, NY, United States; RIMC, Dr Rela Institute & Medical Center, Chennai, India; UHB, University of Birmingham Hospitals, Birmingham, United Kingdom; UTHSA, University of Texas Medical San Antonio, San Antonio, TX, United States.

time period. At University of Texas Medical San Antonio (UTHSA), although the impact of COVID-19 caseload was much lesser, limited reduction in liver transplant activity was evident due to reduced donor referrals and the cascading effect of allocation of regional livers to high model for end-stage liver disease patients in other centers. LDLT activity was suspended at both centers from March 18, 2020. Toward the end of the study period, transplant activity at UTHSA had recovered—including resumption of LDLT, although resource shortage at New York Presbyterian Hospital has led to continued restriction of activity to only urgent transplants.

United Kingdom

As on May 30, 2020, 269 131 confirmed cases and 37 837 deaths have been reported.[14] London is the hotspot of the pandemic in the United Kingdom. NHS Blood &Transplant, the nodal agency overseeing transplant activity in the United Kingdom has been issuing regular guidance from March 19, 2020, and has regularly modified it based on the evolving national situation[9] (Table 2).

National ODT Activity

Deceased donation reduced sharply by >80% by the beginning of April 2020 due to a combination of less frequent ICU callouts, limited access to donor COVID-19 testing, revision of age criteria for donor identification and shortage of ICU beds (Figures 2 and 3; Figure S3, SDC, http://links.lww.com/TP/B988). Liver transplant activity reduced in-line with donation activity and was restricted to super-urgent and urgent cases. Reducing pressure on ICU resources and improved access to donor COVID-19 testing led to a partial recovery in activity toward the end of the study period along with limited resumption of LDLT activity.

Center-wise Activity

Kings College & Hospital, London, saw an early reduction in liver transplant numbers, with reduction of activity from the second week of March (Figure 4; Figure S4, SDC, http://links.lww.com/TP/B988). Nearly 90% of ICU bed capacity was utilized for COVID patients, with a single COVID-free ICU designated for transplant and other non-COVID cases. UHB escaped the initial surge of COVID-19 cases and activity could be maintained until the last week of March. The number of transplants dropped sharply after, in-line with increasing COVID-19 cases in the West Midlands region and extensive reallocation of ICU capacity for COVID-19 patients. Toward the end of the study period, liver transplantation activity at both centers was recovering with increasing deceased donations and reduction in COVID-related workload.

India

The course of COVID-19 pandemic has been much slower in India with the number of positive cases crossing the 165 000 mark on May 30, 2020. Case-fatality rate appears to be much lower than in the United States and Europe. Noting the rapidity of COVID-19 spread in Europe and the United States, the Government of India ordered a preemptive 3-week national-wide lockdown on March 24 with complete cessation of all public transport,

commercial, and entertainment establishments.[15] This has now been extended thrice till the end of May 2020 and is expected to be continued to a limited extent in June. Initial guidance from Liver Transplant Society of India and National Organ & Tissue Transplant Organization had advised cessation of all elective living donor transplant activity except for acute liver failure (ALF) and compulsory testing for all potential donors and recipients[10,16] (Table 2). This guidance was later revised to allow centers to perform LDLT for acute on chronic liver failure and other sick patients using center-specific criteria.

Overall ODT Activity

There was a near-complete cessation of deceased donation throughout India from the third week of March due to the cumulative effect of the national lockdown-related travel restrictions, restrictions put in by regulatory authorities and limited COVID-19 testing facilities (Figures 2 and 3; Figures S5 and S6, SDC, http://links.lww.com/TP/B988). As suspension of LDLT was also advised except for patients with ALF, liver transplantation activity in India came to a near standstill in the second half of March despite comparatively low COVID-19 caseload and no significant stress on ICU capacity. Following a review of the situation, criteria for LDLT were relaxed in the beginning of April to allow transplantation for ALF, acute on chronic liver failure, and sick recipients after COVID-19 testing for both donors and recipients. Regular LDLT activity has now resumed in several Indian centers for selected high-risk patients after donor and recipient testing. Deceased donations has however been slow to restart in both the Indian states studied here. The first deceased donation was facilitated at the end of the study period after a gap of 6 weeks.

Center-wise Activity

The city of Chennai had the lowest COVID-19 caseload among 6 centers surveyed (Figure 4; Figure S7, SDC, http://links.lww.com/TP/B988). Liver transplantation activity (primarily LDLT) at Dr Rela Institute, Chennai, continued till the second week of March, after which there was a suspension of all nonurgent liver transplantations in-line with the national guidance. LDLT was restarted for selected cases in early April 2020 but had to be suspended again due to positive preoperative COVID-19 test in an asymptomatic potential donor. The program was restarted in the second week of May after extensive testing of all staff involved in that donor's evaluation. In Global Hospitals, Mumbai, India, where the COVID-19 caseload is the highest in the country, the LDLT program was also suspended as the number of COVID-19 patients increased in the city with concerns regarding lack of ICU capacity in the city hospitals. Despite the relaxation of restrictions on LDLT in early April, activity has remained very low due to lockdown-related restrictions, until some recovery toward the end of the study period.

Impact of COVID-19 Pandemic on Hospital Policies

Survey of the participating centers revealed significant reallocation of ICU bed capacity and transplant staff for COVID-19 patient care especially during the surge period in United States and United Kingdom (Table 3). Resource reallocation in Indian centers was relatively low during most of the study period, in view of the slow increase in caseload. However, increasing allocation of ICU beds and transplant staff was seen in both Indian centers toward the end of the study period as case numbers continue to increase. All the 6 centers had developed clear protocols for separating COVID and non-COVID areas to avoid crossinfections and ensure a COVID-19 free clinical pathway for transplant patients. Enhanced personal protection equipment usage by the staff in all clinical areas and a trend toward minimizing patient visits to hospital by increased use of web-based consultations was noted. All centers had established protocols for testing potential donors and recipients, although none of the centers were performing routine testing of the transplant staff for COVID-19 infection. Blood products availability for liver transplantation was not a limiting factor in any of the centers, partly due to reduced trauma patients and elective surgery requirements. This is, however, likely to be an issue in the near future as elective work restarts but blood donation drives may be reduced.

DISCUSSION

The impact of the COVID-19 pandemic on healthcare delivery is going to be enormous regardless of the healthcare model in each country.[17,18] ODT involve multiple stakeholders and is one of the most legislated and regulated clinical specialties. The COVID-19 pandemic is a challenge never encountered by this specialty in its brief history. In a recent publication, Kumar et al proposed a graded reduction in transplant activity taking into consideration the COVID-19 disease load, the urgency of transplantation and resource availability.[19] Given the dynamic course of the pandemic, frequent review of these factors is necessary while changes to national and local policies are made. There have been recent publications regarding the impact of COVID-19 pandemic on ODT in France, Italy, and the United States.[20,21] However, there has been no study investigating the impact at the transplant center level and factors responsible for the same.

While the 3 countries studied have different systems of healthcare provision, ODT is closely regulated in all of them with some notable differences. The National Organ Retrieval Services in the United Kingdom and Organ Procurement & Transplantation Network in the United States manages the logistics of potential donor identification, donor recovery operation, organ allocation, and data collection. In the United Kingdom, organ recovery is performed by regional teams and organs transported to recipient hospitals. In the United States, there is more variability with regard to utilization of regional teams versus teams from the recipient center. Majority are deceased donor liver transplants, although the number of LDLTs performed is increasing in the United States. In India, the regional transplant committees' role is limited to overseeing the transplant waiting lists and organ allocation. Deceased donor identification and counseling is performed by individual hospitals, while the recovery operation is the responsibility of the recipient center. Deceased donation rates are low and >80% of all liver transplants in the country are LDLT.

Deceased donation and liver transplantation activity started shrinking in all 3 countries during the second half

TABLE 3.

Summary of the impact of COVID-19 pandemic on liver transplant units and activity

Unit	KCH	UHB	NYP	UTHSA	GHM	RIMC
Country	United Kingdom	United Kingdom	United States	United States	India	India
Number of COVID-19 patients treated in this facility during the study period	>500	100–500	>500	10–100	100–500	10–100
Resource allocation						
Transplant staff reallocation to COVID-19 care	75% of anesthesia staff and 50% of surgical staff	All anesthetists, 90% of coordinators and 25% of surgical staff	Most of transplant team reallocated to COVID patient care	None	25% medical and anesthetic staff. No surgeons	50% of medical and ICU staff. 25% surgeons
% ICU capacity reallocation for COVID-19	At peak period, >80% ICU capacity was diverted for COVID patients. Single COVID-free ICU maintained for posttransplant patients	At peak period, >80% ICU capacity was diverted for COVID patients	ICU capacity dramatically increased and utilized during surge period for COVID patients. One unit for COVID-free patients was still maintained	Designated COVID unit. 20% of adult ICU bed capacity. Not completely utilized	Designated COVID unit. 50% of hospital ICU bed capacity	Designated COVID unit. 50% of hospital ICU bed capacity
Transfusion medicine logistics	No restriction for transplants	No restriction for transplants	No issues so far. May be an issue once elective surgery starts due to reduced blood donation drives	No issues at present	No issues but prior notification required	48 h prior notification for elective surgeries
COVID and the recipient						
COVID-19-related mortality on the waiting list	Information not available	Information not available	Information not available	Information not available	Information not available	2 potential LDLT recipients
COVID-19 infections in long-term liver recipients	3 cases No mortalities	Data not available	Data not available	Nil	2 cases (mild infection in both) No mortality	Nil
COVID-19 infections in peritransplant period	None	None	1, recovered	None	None	None
Liver transplantation activity						
Changes in transplant criteria in view of COVID-19 restrictions	UKELD > 55, marginal HCC	UKELD > 60, UKELD > 55 with complications, marginal HCC	High MELD and HCC. Low MELD patients with anticipated low resource utilization and short postoperative course	MELD > 25, HCC with exception points, highly symptomatic recipients	ALF, ACLF, MELD > 25, CTP > 12, SBP or difficult to control HRS	ALF, ACLF and marginal HCC, needing hospital admission for liver-related complications
DDLT activity	Increasing	Increasing	Continuing with regular assessment of logistics and risk-benefit ratio	Increasing	Continuing, but no donor offers	Continuing, but no donor offers
LDLT activity	Restarted	Remains suspended	Remains suspended	Restarted	Restarted—May 15	Restarted after a temporary stop on May 9, 2020

Continued next page

TABLE 3. (Continued)

Unit	KCH	UHB	NYP	UTHSA	GHM	RIMC
COVID-19-related transplant cancelations during the study period	1 ALF patient tested positive, did not proceed with super-urgent listing	5 liver offers not taken due to ICU bed nonavailability	Nil	2 DDLT canceled due to recipient refusal. One LDLT canceled as a potential living donor tested COVID-19 positive	1 cancelation due to nonavailability of COVID-19 testing	Two LDLT canceled as the potential donors tested COVID-19 positive before transplant
COVID testing for donors and recipients						
COVID-19 testing for deceased donors	Nasopharyngeal swab/BAL PCR	Nasopharyngeal swab/ BAL PCR	Nasopharyngeal swab/BAL PCR	Nasopharyngeal swab/BAL PCR	Nasopharyngeal swab/BAL PCR and CT thorax	Nasopharyngeal swab PCR for donor and immediate family
COVID-19 testing for living donors	Yes, single NP swab PCR	Not performing LDLT at present	Not performing LDLT at present	Yes, single NP swab PCR within 24 h of surgery	Yes, NP swab PCR and chest CT	Yes, 2 NP swab PCR and chest CT for donor and carer
COVID-19 testing for recipients	Single NP swab PCR before liver transplant	Two NP swab PCR tests and CT thorax before transplant.	Yes, single NP swab PCR at transplant	Routine testing for all DDLT and LDLT recipients since April 24 (within 24 h of transplant)	NP swab PCR and negative chest CT	NP swab PCR and negative chest CT for LDLT recipient and carer
Transplant staff safety						
Changes in work pattern	Enhanced PPE usage. Telephone clinics, reduction in face-to-face meetings	Enhanced PPE usage. Telephone clinics. Blood tests at local hospitals.	Enhanced PPE usage in all clinical areas. Separation of COVID and non-COVID areas	Enhanced PPE for staff, limited interpersonal contact. Meetings over webex	Enhanced PPE. Restricted face-face clinic appointments. E-consultations	Enhanced PPE in all clinical areas. Restricted face-face clinic appointments. E-consultations
COVID-19 infection in transplant team	Yes	No	Yes	Nil	Yes	None
Routine, periodic COVID-19 testing for transplant team	No	No	No	No	No	No

ACLF, acute on chronic liver failure; ALF, acute liver failure; BAL, broncho alveolar lavage; DDLT, deceased donor liver transplantation; GHM, Global Hospital, Mumbai; HCC, hepatocellular carcinoma; ICU, intensive care unit; KCH, Kings College & Hospital, London; LDLT, living donor liver transplantation; LT, liver transplantation; MELD, model for end-stage liver disease; NP swab PCR, nasopharyngeal swab RT-PCR for SARS-CoV-2; NYC, New York City; NYP, New York Presbyterian; PPE, personal protection equipment; RIMC, Dr Rela Institute, Chennai; UHB, University Hospitals Birmingham; UTHSA, University of Texas Health San Antonio.

of March with its maximum impact during April 2020 (Figures 2 and 3). However, there are interesting differences in the timeline of this reduction and its severity. Reduction in deceased donation and liver transplantation followed the course of COVID-19 caseload in the United Kingdom and United States. Both countries used graded measures in response to the increasing pressure on healthcare infrastructure (Tables 2 and 3). However, the reduction in deceased donation was significantly lesser in the United States than in the United Kingdom. Possible reasons could be the strong regional variation in COVID-19 caseload in the United States[13] and the higher per capita ICU bed resources in the United States.[22,23] The former could have allowed the less affected regions to continue with deceased donation while the latter factor could have ensured that sufficient ICU beds were available in hospitals to facilitate potential deceased donation. Additionally, while the United Kingdom had a national mandate for lockdown, the timing and degree of the US lockdown varied locally based on individual state governments. Conversely in India, deceased donation and liver transplantation completely stopped from the third week of March although the country had a much lower COVID-19 caseload. Reasons included the early restrictions brought in by regulatory authorities, prolonged nation-wide lockdown, reduced road traffic accidents, limited access to COVID-19 testing, and concerns regarding safety of patients and transplant teams. Finally, for individual hospitals and teams in India focused on making preparations for a pandemic situation, ODT was not a priority.

The period of this study has coincided with a period of intense learning for both transplant organizations and transplant programs to identify clinical priorities and develop measures to mitigate the impact of the pandemic on organ transplantation. This knowledge is now helping programs develop locally relevant protocols to resume transplant activity after assessing the balance of risk-benefit for each patient, the logistics of donor and recipient testing for COVID-19 and the capacity of hospital resources to manage both the transplant and COVID-19 workload safely (Table 3).

Our study shows that ODT activity in all 3 countries has started to recover by the middle of May 2020. As expected, the focus of recovery has been on deceased donation and deceased donor liver transplantation in the United States and United Kingdom, while it has been on the resumption of LDLT activity in India. Within these countries, recovery varied between centers based on local factors. For instance in United States, recovery at UTHSA, with a low COVID-19 caseload was faster than at New York Presbyterian. In the United Kingdom, recovery at UHB was faster and better than at Kings College & Hospital, London. In India, recovery at Dr Rela Institute, Chennai, was faster than at Global Hospitals, Mumbai, India, due to the former's primarily LDLT practice and lesser dependence on deceased donation. The situation, however, remains fluid and organizations should be responsive to new evidence and information regarding the virus and its spread. Greater care may be particularly necessary in the Indian scenario, as the resumption of ODT activity coincides with the withdrawal of the nationwide lockdown and continued increase in COVID-19 infections.

Healthcare resources will continue to be strained by this pandemic. The aim for the transplant community during this period should be to maintain sufficient liver transplantation activity to cater to patients needing urgent transplants while keeping other patients stable on the waiting list.[19,24] Of note, all units maintained a capacity to perform urgent transplants during this period. Our study has demonstrated extensive reallocation of resources and personnel to deal with the pandemic. The nature of reallocation has varied and tailored to the actual severity of the local situation ranging from "isolating COVID-19 patients" in low caseload regions to "isolating non-COVID patients" in high-caseload regions.

Transplant teams are at an increased risk of acquiring COVID-19 infection because of the larger, multidisciplinary nature of their teams, repeated contact with ICU patients and the need to travel for donor runs. Measures such as smaller teams to cover clinical areas by rotation, increased use of personal protection equipment, reduce the need for teams to travel for organ recovery and transplantation and mandatory COVID-19 testing for all donors and recipients have all implemented in these 6 centers to protect the health of the transplant teams. While none of the centers are currently providing routine periodic testing of transplant teams, the situation may change as the pandemic progresses.

As the pandemic settles and we move into the phase of chronic endemicity, the rate of and degree to which deceased donation recovers in various geographic areas of the United States remains to be seen. During this recovery period, LDLT with sufficient safeguards would be an important option for centers, which are in the hardest hit areas to embrace as deceased donation gradually recovers. In India where deceased donation is more sensitive to such profound disruptions, complete recovery may take much longer, at least partly due to the reluctance of private institutions to consider deceased donation in view of possible legal and financial implications of COVID-19 infection. This may, however, be an opportunity for India to upgrade its current state level ODT committees to more integrated systems with the mandate to actively facilitate deceased donation without the typical constraints of individual hospitals or transplant teams.

There are several drawbacks to this study. The pandemic is still evolving and hence the trends in ODT presented over this short period may not be representative of its future course. The activity during this study period has been compared with the average annual activity of each country, which overlooks any seasonal variations. Indian data could only be obtained for 2 states, and the United Kingdom national data are incomplete for the first 2 weeks of the study period. Despite these shortcomings, we have established a significant contraction of organ donation and liver transplantation activity with early signs of recovery in the 3 countries and evidence that this reduction in activity is multifactorial and related to national, regional, and local factors.

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REFERENCES

1. World Health Organization. *Coronavirus disease (COVID-19) pandemic*. Available at https://www.who.int/emergencies/diseases/novel-coronavirus-2019. Accessed April 15, 2020.
2. Royal College of Surgeons of England. *COVID-19: good practice for surgeons and surgical teams*. Available at https://www.rcseng.ac.uk/standards-and-research/standards-and-guidance/good-practice-guides/coronavirus/covid-19-good-practice-for-surgeons-and-surgical-teams/. Accessed April 13, 2020.
3. American College of Surgeons. *COVID-19: elective case triage guidelines for surgical care*. Available at https://www.facs.org/covid-19/clinical-guidance/elective-case. Accessed April 13, 2020.
4. Ahn C, Amer H, Anglicheau D, et al. Global transplantation COVID report March 2020. *Transplantation*. 2020. doi: 10.1097/TP.0000000000003258
5. The Transplantation Society. *Guidance on coronavirus disease 2019 (COVID-19) for transplant clinicians*. Available at https://tts.org/23-tid/tid-news/657-tid-update-and-guidance-on-2019-novel-coronavirus-2019-ncov-for-transplant-id-clinicians. Accessed April 17, 2020.
6. International Liver Transplantation Society. *COVID-19 statement from the infectious diseases and liver transplantation SIG*. Available at https://ilts.org/covid-19-statement-from-the-infectious-diseases-and-liver-transplantation-sig/. Accessed April 22, 2020.
7. Fix OK, Hameed B, Fontana RJ, et al. Clinical best practice advice for hepatology and liver transplant providers during the COVID-19 pandemic: AASLD expert panel consensus statement. *Hepatology.* 2020;72:287–304.
8. *WHO Director-General's opening remarks at the media briefing on COVID-19—11 March 2020*. Available at https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020. Accessed April 23, 2020.
9. *COVID-19: Advice for clinicians. ODT clinical: COVID-19: Clinical advice. NHS: Blood and transplant*. Available at https://www.odt.nhs.uk/covid-19-advice-for-clinicians/. Accessed April 23, 2020.
10. NOTTO: National Organ & Tissue Transplant Organization. *News & events*. Available at https://notto.gov.in/news-events.htm. Accessed April 23, 2020.
11. UNOS: United Network for Organ Sharing. *COVID-19 and solid organ transplant*. Available at https://UNOS.org/COVID. Accessed April 23, 2020.
12. Government of Tamilnadu. *TRANSTAN-Transplant Authority of Tamil Nadu*. Available at https://transtan.tn.gov.in/. Accessed April 20, 2020.
13. CDC: Centers for Disease Control and Prevention. *Coronavirus disease: Cases in the US*. 2020. Available at https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html. Accessed April 23, 2020.
14. Coronavirus cases in the UK: daily updated statistics. *Gov.uk website*. Available at https://www.gov.uk/guidance/coronavirus-covid-19-information-for-the-public. Accessed May 23, 2020.
15. *Government of India issues orders prescribing lockdown for containment of COVID-19 epidemic in the country*. Available at https://pib.gov.in/newsite/. Accessed April 15, 2020.
16. Saigal S, Gupta S, Sudhindran S, et al. Liver transplantation and COVID-19 (coronavirus) infection: guidelines of the Liver Transplant Society of India (LTSI). *Hepatol Int*. 2020:1–3. doi:10.1007/s12072-020-10041-1
17. Chowell G, Mizumoto K. The COVID-19 pandemic in the USA: what might we expect? *Lancet.* 2020;395:1093–1094.
18. Kinross P, Suetens C, Gomes Dias J, et al. Rapidly increasing cumulative incidence of coronavirus disease (COVID-19) in the European Union/European Economic Area and the United Kingdom, 1 January to 15 March 2020. *Euro Surveill*. 2020;25:2000285. doi:10.2807/1560-7917.ES.2020.25.11.2000285
19. Kumar D, Humar A. CMV immune monitoring-where do we go from here? *Am J Transplant.* 2020;20:1961–1962.
20. Loupy A, Aubert O, Reese PP, et al. Organ procurement and transplantation during the COVID-19 pandemic. *Lancet.* 2020;395:e95–e96.
21. Angelico R, Trapani S, Manzia TM, et al. The COVID-19 outbreak in Italy: initial implications for organ transplantation programs. *Am J Transplant.* 2020;20:1780–1784.
22. Prin M, Wunsch H. International comparisons of intensive care: informing outcomes and improving standards. *Curr Opin Crit Care.* 2012;18:700–706.
23. Niall McCarthy. The countries with the most critical care beds per capita. *Statista Infographics*. 2020. Available at https://www.statista.com/chart/21105/ number-of-critical-care-beds-per-100000-inhabitants/. Accessed April 15, 2020.
24. Wall AE, Pruett T, Stock P, et al. Coronavirus disease 2019: utilizing an ethical framework for rationing absolutely scarce health-care resources in transplant allocation decisions. *Am J Transplant*. 2020. doi:10.1111/ajt.15914