Opportunities and Challenges of Expanded Criteria Organs in Liver and Kidney Transplantation as a Response to Organ Shortage

by Harvey Solomon, MD

Due to changes in age, and quality of both liver and kidney donors, the use of Expanded Criteria Donors and Donation after Cardiac Death organs will rise to meet the needs of increasing numbers of patients awaiting transplant.

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Abstract

In 1989, there were 19,000 patients on the UNOS (United Network of Organ Sharing) wait list for organs compared to 110,000 today. Without an equivalent increase in donors, the patients awaiting these organs for transplant face increasing severity of illness and risk of dying without receiving a transplant. This disparity in supply and demand has led to acceptance of organs with lower than expected success rates compared to previous standard donors variously defined as extended criteria donors in order to increase transplantation. The reluctance to wider use of these types of organs is based on the less than expected transplant center graft and patient survival results associated with their use, as well as the increased resources required to care for the patients who receive these organs. The benefits need to be compared to the survival of not receiving a transplant and remaining on the waiting list rather than on outcomes of receiving a standard donor. A lack of a systematic risk outcomes adjustment is one of the most important factors preventing more extensive utilization as transplant centers are held to patient and graft survival statistics as a performance measure by multiple regulatory organizations and insurers.

Newer classification systems of such donors may allow a more systematic approach to analyzing the specific risks to individualized patients. Due to changes in donor policies across the country, there has been an increase in Extended Criteria Donors (ECD) organs procured by organ procurement organizations (OPO) but their uneven acceptance by the transplant centers has contributed to an increase in discards and organs not being used. This is one of the reasons that wider sharing of organs is currently receiving much attention. Transplanting ECD organs presents unique challenges and innovative approaches to achieve satisfactory results. Improved logistics and information technology combined strategies for improving donor quality with may prevent discards while insuring maximal benefit. Transplant centers, organ procurement organizations, third party payers and government agencies all must be involved in maximizing the potential for ECD organs.

What is an Extended Criteria Donor Kidney?

Extended Criteria Donors are those donors with increased risk factors to the recipient for graft or patient mortality or morbidity.

Table 1
Percentage of All Deceased Kidney Donors Who Were Expanded Criteria (ECD) Donors by Region of Utilization and Year of Recovery

	YEAR OF RECOVERY					
UNOS Region	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**
1	22.3%	25.6%	25.4%	22.1%	23.5%	23.8%
2	31.0%	32.0%	29.0%	32.4%	29.2%	30.7%
3	21.5%	24.9%	23.9%	23.0%	28.0%	24.3%
4	20.5%	19.6%	18.8%	22.9%	18.8%	20.2%
5	19.5%	20.7%	19.2%	21.6%	19.5%	20.1%
6	17.9%	20.4%	23.4%	16.3%	18.9%	19.4%
7	25.3%	23.1%	26.4%	25.0%	27.9%	25.5%
8	18.2%	21.1%	17.0%	18.5%	19.3%	18.8%
9	30.7%	32.9%	33.0%	32.3%	33.7%	32.6%
10	20.9%	24.7%	24.8%	21.0%	24.1%	23.1%
11	20.3%	22.8%	22.7%	26.1%	23.3%	23.1%
Total	22.6%	24.3%	23.6%	24.2%	24.4%	23.9%

Table 2
Kidney Donor Risk Index Parameters Associated with Increased Graft Loss

- ✓ Donor age
- ✓ Race
- ✓ History of Hypertension
- ✓ History of Diabetes
- ✓ Serum Creatinine Level
- ✓ Cerebrovascular Cause of Death
- ✓ Height
- ✓ Weight
- ✓ Donation After Cardiac Death
- ✓ Hepatitis C virus (HCV) Status
- ✓ Human Leukocyte Antigen B and DR Mismatch
- ✓ Cold Ischemia Time
- ✓ Double or En Bloc Transplant

The definitions are organ specific but have some general similarities such as age, co morbidities and length of cold ischemic time. This criteria of ECD kidneys was originally devised in 2002 by UNOS, (See Table 1) and included age greater than 60 or donors from 50 and 59 with at least two of the three following criteria: death from stroke, history of hypertension, and terminal pre- donation creatinine level of >1.5 mg/dl. Compared to "ideal" donors age 10-39 without risk factors the relative risk of graft loss was 1.7. [1] Studies validate that the ECD kidneys have higher rates of delayed graft function and shorter graft survival but patients are advantaged when transplanted with these organs when compared to remaining on dialysis or on the waiting list. [2, 3] The process of defining ECD was initiated with the hopes that patients could choose if they would accept the an older donor and the inherent risks over remaining on dialysis. This was modeled after the experience in Spain, which had shown that older donors could be used successfully. Initially the definition included these factors only but transplant centers have added other clinical factors over the years including calculated GFR, biopsy results, presence and duration of diabetes mellitus and other factors some of which were tested in the original evaluation of a definition for ECD but were not kept in the final version by UNOS.

There are several limitations of the current definitions of ECD in that it was derived from clinical practice and did not include biopsy results, cold ischemic time and other discriminating data. Improvements in quantification of risk have been proposed with criteria developed as KDRI (Kidney Donor Risk Index) and include both donor and recipient factors to determine graft survival benefit after kidney transplant[4] (See Table 2). These parameters include 14 donor and transplant factors including age, height, weight, race, creatinine, cause of death, presence of hypertension, diabetes, hepatitis C, cold ischemic time, dual or en bloc transplant and HLA matching. A downloadable algorithm is available on the web and is currently used by many centers, but to date is not UNOS policy or effects organ allocation.[5]

Liver ECD Definitions Are Different From Kidneys

The concept of ECD livers is not uniform as is for kidneys. Acceptance of the age criteria and cause of death criteria were adopted by some but liver steatosis, cold ischemia and the importance of recipient illness severity which are of greater importance in the outcomes of liver transplantation were not. Tector defined ECD for livers

age >59years, BMI >34.9, maximum AST/ALT>500, maximum, bilirubin >2.0, peak serum sodium >170, HBV/HCV/HTLV reactive, donation after cardiac death, cold ischemia time >12 hours, ICU stay >5 days prior to donation, three or more pressors simultaneously, extensive alcohol abuse, cancer history, active meningitis or bacteremia, and/or significant donor liver trauma [7]. Renz[8] included age >65 years, donation after cardiac death, positive viral serology (Hepatitis B or C), split-liver grafts, hypernatremia, prior carcinoma, steatosis, and behavioral high-risk donors. Similarly, the UCLA group defined ECD factors as donor age >55 years, donor hospital stay >5 days, cold ischemia time >10 hours, and warm ischemia time >40 minutes.[9] Comparison of results is compromised by this lack of standard definitions across the country. Recently, the Donor Risk Index (DRI) grading system has been developed and increasingly accepted as a means to correlate postoperative failure for donor factors and cold ischemic time. The DRI parameters measured are age, cause of death, race, DCD, partial or split liver graft, height, organ location, and cold ischemic time. [6]

Donation After Cardiac Death

While most donors are still declared brain dead and maintain circulation until organ recovery, an increasing number are derived from cardiac death donors in a controlled setting (Donation after Cardiac Death or DCD). In renal transplants, ECD and DCD are considered within the same risk category, but for livers the DCD grafts stand alone as a risk factor for graft performance both short- and long-term. [20] DCD kidney and liver grafts have increased risks due to obligatory warm ischemia time (WIT) up to 30 minutes for livers and 60 minutes for kidneys. Warm ischemia time is defined from the time of death to actual retrieval from the donor. These types of donors are usually restricted to younger donors <60 years of age. The use of DCD kidneys for kidney transplants has increased over ten fold in the past decade.[13] The injury associated with WIT does increase the risk of delayed graft function or need for at least one dialysis treatment post transplant but does not increase the overall graft survival. Using kidney s from these donors has lead to decreased waiting times in some areas, and increased rates of transplantation.

In contrast to the number of DCD kidneys which continues to rise the use of DCD liver grafts reached a peak in 2006 and has since declined.[10,13] This is due to the greater concerns of risks of subsequent ischemic bilopathy which may be as high as 30%. It is thought to be due to the tenuous arterial supply to the small bile ducts that does not perfuse adequately during the recovery period, once pulsatile cardiac function ceases. The ischemia injury to the bile duct leads to biliary structuring and can limit graft survival significantly. Intrahepatic bile duct strictures lead to prolonged morbidity and may require re-transplantation.. Currently, there is no exception points granted in the allocation system for these patients, and if their graft fail, they are offered no priority for an expeditious re-transplant.

Disparity Between Organ Supply and Listed Patients

Despite the increase in using alternate sources of organs, there continues to be a significant disparity between available organs and patients listed. In 2009, there were 88,000 kidney and 16,000 liver patients listed. The number of cadaveric donors peaked in 2006 due to a national effort to increase donors at slightly over 8,000, and has since leveled off. While the number of procured ECD kidneys rose over the past decade nationwide the transplant rate was only 57.5%. On the other hand, DCD kidney utilization has increased dramatically from 131 in 1999 to 1,181 in 2008. The percentage of DCD kidneys transplanted from those recovered has remained fairly high, between 81 to 90 percent.

While the number of listed patients continues to increase the number of transplants has slightly decreased with 16, 067 kidneys and 5,817 livers.[10, 11,13] The number of patients listed for kidney transplants continues to rise per year, outpacing transplants resulting in longer duration on dialysis. [13, 14] The lack of organs has resulted in extended waiting times and deaths on the waiting list. For end stage renal patients dialysis is clearly inferior to transplant in survival and quality of life. [3, 12] As older dialysis patients are increasingly added to the waitlist, there is less opportunity to receive a kidney. Patients over 60 years of age, when listed, have only a 50/50 chance dying before receiving a transplant. [15] Survival after a kidney transplant in the older population is double that of remaining on dialysis. At five-year interval 75% percent of the transplant patients are alive versus less 30 percent alive on dialysis. [17, 18]

Because of shortened life span, there is a strong advantage for offering older recipients ECD kidneys as many die with a functioning graft and have a survival benefit compared to dialysis with any functioning kidney transplant. [2, 16]

Standard Criteria Donors Decreasing as the Donor Population Ages

In 1988 the percentage of donors 18-34 years of age was 40.5% and in 2010 it was 27.3%. The number of

donors under the age of 50 has shrunken proportionally over the years (78.1 percent) in 1999 to (65.7 percent) 2008 and the number of donors with co-morbidities and death due to stroke and hypertension has risen. There has been a trend in the aged donor potential both in absolute numbers and percentages. For ages 50-64 it has decreased from 10.8% to 22.3% and 65 and above from 0.8% to 7.3%. [10, 11, 13] These demographic factors have increased the need for expanding the use of older donors and DCD grafts.

Living Donation

Another alternative to cadaveric donor sources is the use of living donors. Despite improved laparoscopic surgical techniques the number of living kidney donors peaked around 2005 and has since decreased. [13, 20] Much attention has been directed to expanding living donors through paired exchanges. The exchange involves recipients with donors, but donors that for immunological reasons and/or ABO blood typing, are not candidate s to donate to their recipients but could be exchanged for another recipients donor. While this idea carries some increase, the actual transplants are limited. An even greater decrease in living liver donors has occurred due to a much heightened awareness of the immediate donor risks and recent papers in the literature that demonstrate long-term risk in some living donor liver donors. [19]

Cause of Death

Along with the ageing of the donor population, the cause of death has shifted to more cerebral vascular accidents and anoxic injuries from traditional traumatic causes of brain death. Donors who die from these types of injuries are also at higher risk of other organ dysfunction due to co-morbid conditions such as diabetes, peripheral vascular disease, hypertension and cardiac disease. Due to improvements in accident rates, seatbelt laws, and mandatory helmet laws donors with head injury as a cause of death has decreased in the past five years. [21]

High Risk Donor

Another option in the donor pool is the use of organs from patients who have high risk behavior. In 1994, the CDC (Centers for Disease Control) defined the criteria for high risk donors and an expanded definition is currently being implemented. In general, the performance of high risk donor organs is good but there is an increased risk due to specific donor characteristics for transmission of diseases with to those recipients. Definition of such donors include those positive for hepatitis, or a history of high risk behavior defined as intravenous or other illicit drug use, sex for money, homosexual behavior that is high risk (i.e. multiple partners) prison for greater than one year, non-professional tattoos within a year of donation and having sex with someone known to have HIV. High risk for the CDC revolves around the particular donor behavior that would put them at risk for HIV conversion. For those CDC high risk donors, NAT testing (nucleic acid amplification) has shortened the window of potential exposures. It has thus lessoned but not eliminated the risks. High profile transmissible diseases receive much media attention and may deter centers from utilizing such donors after an event. Faced with a continuing risk of waiting list deaths it is essential to educate the prospective recipients of these types of donors which make up 9% of donors and have a high discard rate. The demographics of these particular donors are usually young with limited co-morbid disease. It is a balance of acceptable risk for the potential recipient of HIV versus death from their organ failure in some cases. Another category of expanded risk donors includes patients with malignancies particularly primary intracranial malignancies which are accepted by some but not all transplant centers. Recipients are educated at the time of listing for transplant, and then consented again at the time of the actual procedure. These types of donor s are not used without the consent of the patient, and the center. Follow up surveillance of recipients and communicating any findings between centers of recipients is an important step in tracking the serological results; however, graft performance from these organs is good both in the short- and long-term.[22]

Results of Use of ECD Kidneys

A comprehensive review of the all renal reports by Pascual[23] showed that candidates listed for ECD were more likely to get transplanted with any type of donor. There was a 77% greater risk of graft failure than those who received a non-ECD kidney transplant with a mean graft survival of only half that of an SCD. This study confirmed that there was a significant advantage in older recipients receiving these transplants as compared to their waitlist mortality. Factors such as biopsy results were not clearly stated in the review but given the variability in interpretations, there is question of the overall benefit of using biopsies at all. There is a great variability amongst center, for listing for ECD kidneys with 25% of centers listing over 90% of the patients on the ECD list and 25% listing less than a 20% of their patients. Only selected ECD centers showed reduced

waiting times for their patients. [24] The current system has not shortened the allocation times since some centers list patients for ECD but have low rates of acceptance of such organs thus extending the cold ischemic time. Using the proposed KDRI scoring system the highest quintile had an adjusted 5-year graft survival of 63%, compared with 82% and 79% in the lowest KDRI quintiles.[4]

A key reason for limiting use of ECD kidneys to younger patients is the concern that there is a reduced half life for ECD and subsequent need for re-transplant which may be precluded by sensitization. Utilizing an estimate of glomerular filtration rate (GFR) may be of use since the creatinine can vary significantly. If a donor is considered to have significantly decreased renal function (GFR 40-60 ml/min) a dual kidney transplant so called "two for one" is also an option. [25]

The financial costs of ECD kidneys often may be a determining factor for use for centers as the cost per case is increased as much as $30,000 as although the use of pulsatile perfusion may reduce the cost as well as improve the function. The savings provided by use of perfusion amounted to approximately $3,000 in the postoperative period.[26, 27]

ECD Liver

While reduced graft survival of kidneys over the course of years is the consequence of ECD utilization, the use of ECD livers has direct affects on early mortality. A liver with a DRI of >2 had a graft survival of only 80.3% at three months, 71.4% at one year and 60% and three years compared to a DRI score of 1 the comparable survivals are 90.3%, 85% and 78.7%. The discard rates also increased more than three fold from 4.1% to 12.5% [6]. Single center results vary from no significant difference [7,8] to a significant decrease in graft and patient survival[9] between use of extended and standard donors. A poor functioning liver in the post-operative setting is not tolerated particularly in older and sicker patients. [9] ECD livers have been reported to have a higher mortality, re-transplant rate and length of stay. A match of donor and recipient factors was modeled by Merion in the Transplant Benefit Model which also takes into account waiting time mortality.[28] Regarding DCD livers, that long-term morbidity of biliary strictures at one year occurring in over 30% versus 10% in SCD and significantly worse patient and graft survival at one and three years [29] has led to a significant decrease over the past five years.[11] Encouraging preliminary evidence that ex vivo hepatic artery fibrinolytic flush may improve this could reverse this trend.[30]

The financial costs are significant even if the patient survives and ultimately benefits. The cost of utilizing an ECD liver has also been estimated in terms of an additional hospital stay of greater than 10 days for high risk donors in stable patients and greater than 20 days for very high risk donors in the sickest patients. The resulting cost increases are $48,000 and $84,000 respectively.[31]

Lacking in registry data is the inclusion of critical liver biopsy data. It has been estimated that fatty liver disease is present in 25-30% of the donor population[32] and over 30% macrosteatosis major factor in early liver dysfunction.[33]. Strategies to improve function of steatotic livers include minimizing cold ischemic time [34] and more recently ex vivo perfusion. [35, 36]

Conclusion

Due to changes in age, and quality of both liver and kidney donors the use of ECD and DCD organs will rise to meet the needs of increasing numbers of patients awaiting transplant. A necessary component is the understanding that there will be additional costs to the system and some decrease in graft survival requiring adjustments in both the risk/benefit analysis and reimbursement rates. The focus of post-transplant results versus total survival of all listed patients is a major shift that will require the combined input of transplant centers, OPOS, government regulators and third party payers. As geographic disparities shrink organs which are not used locally will increasingly be shared over wider distribution areas. The limitations of this is logistic and primarily in extended cold ischemic time. It is expected that future innovations in preservation techniques will contribute to improving graft function particularly for extended criteria donors.

References

1.Port FK, Bragg-Gresham JL, Metzger RA et al. Donor characteristics associated with reduced graft survival: an approach to expanding the pool of kidney donors. Transplantation 2002; 74: 1281 – 1286.

2.Ojo, A O, J A Hanson, H Meier-Kriesche, C N Okechukwu, R A Wolfe, A B Leichtman, L Y Agodoa, B Kaplan, and F K Port. 2001. Survival in recipients of marginal cadaveric donor kidneys compared with other recipients and wait-listed transplant candidates. Journal of The American Society Of Nephrology12, no. 3: 589-597.

3. Merion, Robert M, Valarie B Ashby, Robert A Wolfe, Dale A Distant, Tempie E Hulbert-Shearon, Robert A Metzger, Akinlolu O Ojo, and Friedrich K Port. 2005. Deceased-donor characteristics and the survival benefit of kidney transplantation. Jama The Journal Of The American Medical Association 294, no. 21: 2726-2733.

4. Rao, Panduranga S, Douglas E Schaubel, Mary K Guidinger, Kenneth A Andreoni, Robert A Wolfe, Robert M Merion, Friedrich K Port, and Randall S Sung. 2009. A comprehensive risk quantification score for deceased donor kidneys: the kidney donor risk index. Transplantation 88, no. 2: 231-6.

5. http://itunes.apple.com/us/app/kidney-transplant-donor-risk/id384376925?mt=8

6. Feng, S, N P Goodrich, J L Bragg-Gresham, D M Dykstra, J D Punch, M A DebRoy, S M Greenstein, and R M Merion. 2006. Characteristics associated with liver graft failure: the concept of a donor risk index. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 6, no. 4: 783-790.
7. Tector, A Joseph, Richard S Mangus, Paul Chestovich, Rodrigo Vianna, Jonathan A Fridell, Martin L Milgrom, Carrie Sanders, and Paul Y Kwo. 2006. Use of extended criteria livers decreases wait time for liver transplantation without adversely impacting posttransplant survival. Annals of Surgery 244, no. 3: 439-450.
8. Renz, John F, Cindy Kin, Milan Kinkhabwala, Dominique Jan, Rhaghu Varadarajan, Michael Goldstein, Robert Brown, and Jean C Emond. 2005. Utilization of extended donor criteria liver allografts maximizes donor use and patient access to liver transplantation. Annals of Surgery 242, no. 4: 556-563.
9. Cameron, Andrew M, R Mark Ghobrial, Hasan Yersiz, Douglas G Farmer, Gerald S Lipshutz, Sherilyn A Gordon, Michael Zimmerman, et al. 2006. Optimal Utilization of Donor Grafts With Extended Criteria. Annals of Surgery 243, no. 6: 748-753; discussion 753-755.
10. Tuttle-Newhall, J. E., Krishnan, S. M., Levy, M. F., McBride, V., Orlowski, J. P., and Sung, R. S. (2009). Organ donation and utilization in the United States: 1998-2007. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 9, 879-893.
11. Donation, Organ, Breakthrough Collaborative, and The Optn. 2008. Chapter II Organ Donation and Utilization in the United States , 1999-2008 Overview.Organ The: 1999-2008.
12. Meier-Kriesche, H U, F K Port, A O Ojo, S M Rudich, J A Hanson, D M Cibrik, A B Leichtman, and B Kaplan. 2000. Effect of waiting time on renal transplant outcome. Kidney International 58, no. 3: 1311-1317.
13. HRSR 2009 OPTN/SRTR Annual Report http://optn.transplant.hrsa.gov/ar2009/default.htm
14. Klein, A S, E E Messersmith, L E Ratner, R Kochik, P K Baliga, and A O Ojo. 2010. Organ donation and utilization in the United States, 1999-2008. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 10, no. 4 Pt 2: 973-986.
15. Schold, J., Srinivas, T. R., Sehgal, A. R., & Meier-Kriesche, H.-U. (2009). Half of Kidney Transplant Candidates Who Are Older than 60 Years Now Placed on the Waiting List Will Die before Receiving a Deceased-Donor Transplant.Clinical journal of the American Society of Nephrology CJASN, 4(7), 1239-1245. American Society of Nephrology.
16. Sung, R S, J Galloway, T Mone, R Laeng, C E Freise, and P S Rao. 2008. Organ Donation and Utilization in the United States , 1997 – 2006. American Journal of Transplantation 8, no. Part 2: 922-934.
17. Oniscu, Gabriel C, Helen Brown, and John L R Forsythe. 2004. How great is the survival advantage of transplantation over dialysis in elderly patients? Nephrology Dialysis Transplantation 19, no. 4: 945-951.
18. Danovitch, Gabriel, and Eric Savransky. 2006. Challenges in the counseling and management of older kidney transplant candidates. American journal of kidney diseases the official journal of the National Kidney Foundation 47, no. 4 Suppl 2: S86-S97.
19. Ghobrial, Rafik M, Chris E Freise, James F Trotter, Lan Tong, Akinlolu O Ojo, Jeffrey H Fair, Robert A Fisher, et al. 2008. Donor morbidity after living donation for liver transplantation. Gastroenterology 135, no. 2: 468-476.
20. Rao, Panduranga S, and Akinlolu Ojo. 2009. The alphabet soup of kidney transplantation: SCD, DCD, ECD--fundamentals for the practicing nephrologist. Clinical journal of the American Society of Nephrology CJASN 4, no. 11: 1827-1831.
21.HRSA/OPTN data 2011 http://optn.transplant.hrsa.gov/latestData/rptData.asp
22. Kucirka LM, Singer AL, Segev DL. High infectious risk donors: what are the risks and when are they too high? Curr Opin Organ Transplant. 2011 Apr;16(2):256-61.
23. Pascual, Julio, Javier Zamora, and John D Pirsch. 2008. A systematic review of kidney transplantation from expanded criteria donors. American journal of kidney diseases the official journal of the National Kidney Foundation 52, no. 3: 553-86.
24. Schold, J D, R J Howard, M J Scicchitano, and H-U Meier-Kriesche. 2006. The expanded criteria donor policy: an evaluation of program objectives and indirect ramifications. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 6, no. 7: 1689-1695.
25. Stratta, Robert J, Michael S Rohr, Aimee K Sundberg, Alan C Farney, Erica L Hartmann, Phillip S Moore, Jeffrey Rogers, et al. 2006. Intermediate-term outcomes with expanded criteria deceased donors in kidney transplantation: a spectrum or specter of quality? Annals of Surgery 243, no. 5: 594-601; discussion 601-603
26. Buchanan, P M, K L Lentine, T E Burroughs, M A Schnitzler, and P R Salvalaggio. 2008. Association of lower costs of pulsatile machine perfusion in renal transplantation from expanded criteria donors. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 8, no. 11: 2391-2401.
27. Stratta, Robert J, Phillip S Moore, Alan C Farney, Jeffrey Rogers, Erica L Hartmann, Amber Reeves-Daniel, Michael D Gautreaux, Samy S Iskandar, and Patricia L Adams. 2007. Influence of pulsatile perfusion preservation on outcomes in kidney transplantation from expanded criteria donors. Journal of the American College of Surgeons 204, no. 5: 873-882.
28. Schaubel, D E, M K Guidinger, S W Biggins, J D Kalbfleisch, E A Pomfret, P Sharma, and R M Merion. 2009. Survival benefit-based deceased-donor liver allocation. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 9, no. 4 Pt 2: 970-981.
29. Foley, David P, Luis A Fernandez, Glen Leverson, L Thomas Chin, Nancy Krieger, Jeffery T Cooper, Brian D Shames, et al. 2007. Organ donation after cardiac death. The New England Journal of Medicine 357, no. 3: 209-213.
30. Hashimoto, K, B Eghtesad, G Gunasekaran, M Fujiki, T D Uso, C Quintini, F N Aucejo, et al. 2010. Use of tissue plasminogen activator in liver transplantation from donation after cardiac death donors. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons 10, no. 12: 2665-2672.
31. Clark, Jeanne M. 2006. The epidemiology of nonalcoholic fatty liver disease in adults. Journal of Clinical Gastroenterology 40 Suppl 1, no. March: S5-S10.
32. Selzner, M, and P A Clavien. 2001. Fatty liver in liver transplantation and surgery. Seminars in Liver Disease 21, no. 1: 105-113.
33. Doyle, M. B. M., Vachharajani, N., Wellen, J. R., Anderson, C. D., Lowell, J. A., Shenoy, S., Brunt, E. M., et al. (2010). Short- and long-term outcomes after steatotic liver transplantation. Archives of surgery, 145(7), 653-660.
34. Axelrod, D. A., Schnitzler, M., Salvalaggio, P. R., Swindle, J., & Abecassis, M. M. (2007). The economic impact of the utilization of liver allografts with high donor risk index. American journal of transplantation official journal of the American Society of Transplantation and the American Society of Transplant Surgeons,7(4), 990-997.
35. Monbaliu, Diethard, and John Brassil. 2010. Machine perfusion of the liver: past, present and future. Current Opinion in Organ Transplantation 15, no. 2: 160-166.
36. De Rougemont, Olivier, Stefan Breitenstein, Boris Leskosek, Achim Weber, Rolf Graf, Pierre-Alain Clavien, and Philipp Dutkowski. 2009. One hour hypothermic oxygenated perfusion (HOPE) protects nonviable liver allografts donated after cardiac death. Annals of Surgery 250, no. 5: 674-683.

Disclosure

None reported.