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Hepatitis C-Positive Organs for Liver and Kidney Transplantation—Emerging Data and Current Management Strategies

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Abstract

Purpose of Review We aim to review the current guidelines and emerging data and compare the pros and cons for the use of HCV-positive organs.

Recent Findings Some recent data suggests that the use of HCV-positive livers and kidneys safely increases the organ pool, additionally reducing wait list time, healthcare costs, and mortality.

Summary Despite this therapeutic breakthrough, the demand for organs and waitlist mortality remains high. Every year, thousands of viable hepatitis C-positive organs are discarded. The emerging data regarding transplantation of HCV-positive organs is promising; however, further research is warranted with larger samples. A literature search was conducted using PubMed, using the keywords "transplant recipients," "hepatitis C," "kidney transplantation," "liver transplantation," "direct acting antivirals," and "pre transplant." Only articles in the English language were included.

Keywords Hepatitis C virus · Liver transplant · Kidney transplant · Waitlist · Direct-acting antiviral

Introduction

Organ transplantation is the definitive therapeutic option for eligible patients with end-stage liver and kidney disease. It is well documented that healthcare costs and life expectancy significantly benefit from transplantation [1, 2]. Despite the increasing awareness of organ donation, thousands of viable organs are discarded and the demand surpasses supply [3]. Unfortunately, this disparity is expected to grow during the next 20 years [4].

With the opioid epidemic, the rate of drug-related deaths has increased 200% [5]. The amount of overdose-related organs has dramatically increased from 1.1% in 2000 to 13.4% in 2017 [6]. Today, hepatitis C virus (HCV)-positive organs are still being declined for transplantation due to the general belief of increased risk of disease transmission that potentially may lead to post-transplant complications including rejection and accelerated graft failure [7•]. Since 2011, direct-acting antiviral (DAA) therapy against HCV has dramatically altered cure rates with shortened treatment duration, achieving sustained virological response 12 weeks after therapy initiation in more than 94% of patients for most HCV genotypes [8, 9]. Emerging data, mainly in the kidney transplant population, suggest that DAAs can be safely used in the post-transplant period with rapid sustained virologic clearance resulting in minimal and short duration exposure to the potential adverse effects of HCV-viremia [10, 11].

Several questions remain, including (1) what type of patients should be considered for these type of organs? (2) When should patients be treated with DAAs? (3) What is the best approach for patients waiting for an organ with the new option of getting a HCV-positive organ?

Use of Hepatitis C-Positive Organs for Transplant

As per recent consensus, it is important to differentiate between HCV-viremic (nucleic amplification testing (NAT)-positive) and non-HCV-viremic (HCV antibody (HCV Ab)-positive) organs [12]. A positive HCV Ab organ contains less risk

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of HCV transmission than a NAT-positive one; however, the risk is still not zero. With NAT, it is now possible to detect HCV RNA within 5–7 days from exposure [13]. Therefore, HCV-viremic organs represent those with NAT positivity regardless of HCV Ab status. A positive HCV Ab with NAT negativity may represent three different scenarios: active infection with fluctuating low viral levels, a false-positive HCV Ab, or cured HCV infection through spontaneous clearance or prior treatment. Most of the cases fall into the latter group [14]. Despite these diagnostic improvements, there is still risk for transmission as we are still unable to detect the virus during the first 5–7 days from exposure. This timeframe is known as the eclipse period. Bowring and colleagues reported that the use of HCV-viremic organs has increased dramatically since the advent of DAAs in HCV-infected recipients (from 6.9 to 16.9%), and more importantly, allograft survival remains similar in HCV-positive recipients of HCV-viremic and HCV non-viremic livers. Interestingly, 50% of the transplanted livers were HCV-viremic [15]. The donor testing system continues to evolve. Since 2014, the HCV Ab and NAT have become mandatory for every potential organ to be donated. In 2015, DonorNET allowed centers to consider organs from donors with HCV Ab positivity regardless of NAT positivity.

Historically, HCV-positive organs have been used for HCV-infected recipients without graft survival differences [16–18]. According to the Organ Procurement and Transplantation Network (OPTN), 4.1% of the transplanted solid organs were HCV-positive between 1995 and 2016. Not surprisingly, the post-transplant outcomes of this particular group were inferior compared with the HCV-negative organs due to the lack of DAAs [19, 20]. Since the widespread use of DAAs, studies have shown promising results. Axelrod and colleagues compared pre-DAA versus post-DAA data in liver and kidney transplants, demonstrating that DAA therapy improves HCV-positive transplant outcomes. The main limitation was access to DAAs due to cost and insurance coverage [7•]. Chascsa and colleagues in a multicenter study demonstrated decreased kidney-transplant waitlist time and no difference in graft quality and DAA-related complications [10].

HCV-Positive Liver Transplantation

According to the 2016 OPTN report, 11,340 patients were listed for liver transplantation, but only 7841 liver transplants were performed, which represents a 10% increase from 2015 [21]. This increase was attributed to more deceased donors, directly positively influencing the median waitlist time to 11.3 months. Interestingly, the discard rate for HCV-viremic organs was similar to the HCV-negative organs (9.0% and 8.9% respectively). Based on current OPTN data, there are around 13 thousand patients waiting for a liver transplant in the USA. Despite these improvements, the waitlist mortality remains around 20%, mainly driven by lack of available organs [22].

When considering HCV-viremic livers, it is important to evaluate the donor's age and the organ fibrosis stage. Lai and colleagues found an increased risk of fibrosis in HCV-viremic patients above age 45 years [16]. This is most likely explained by the age-dependent capacity for chronically inflamed hepatocytes to regenerate and proliferate [23]. Current guidelines recommend utilization of livers with biopsy-proven fibrosis of stage 2 (portal fibrosis with few septa) or less [12, 24]. There are still scant data regarding the transplantation of HCV-positive livers into HCV-negative recipients and the current guidelines continue to consider these organs high risk, which limits widespread use.

HCV-Positive Kidney Transplantation

As of today, 95 thousand patients are listed for kidney transplantation. OPTN data from 2016 reported that unfortunately one-fourth of the delisted patients were removed due to severe waitlist illness or death. These data highlight the importance of expanding the organ pool to increase access to transplant [25]. The HCV-prevalence in end-stage renal disease patients is 5–10% [26]. In contrast to the liver transplant population, pre-DAA studies have shown that recipients from HCV-positive kidneys have worse outcomes compared with those receiving HCV-negative allografts [3, 19].

In 2009, a kidney donor risk index (KDRI) for deceased donor kidneys was published to quantify graft failure risk [27]. This scoring system evaluates the quality of the organ and guides organ selection by comparing data from the prior year versus the considered kidney. From a scale of 1 to 100%, the lower the number, the better the organ. HCV-status is considered in this calculator as it was found to be directly associated with graft failure and death—increasing the KDRI by 20% [27]. Five years later, a new kidney allocation system (KAS) was introduced, promoting better donor quality and increased post-transplant survival; this system takes into account the KDPI. Sibuleski and colleagues conducted a retrospective case-control analysis of deceased donor kidney transplants taking into account the KDRI score, HCV antibody, and HCV-NAT status. They concluded that HCV Ab+/NAT− allografts carry minimal risk of viral transmission and are of good quality for transplantation [28••]. These donors tend to be younger, less likely to have comorbidities like diabetes or hypertension, and have better renal function. These data suggest that KDRI should be revised, as the KAS in its current form inappropriately stratifies organ allograft quality by failing to account for the NAT status of the donor, but reflects antibody status only. Durand and colleagues, in an open-label study with 10 HCV-negative kidney transplant candidates who received a positive HCV RNA and positive HCV Ab organ, achieved SVR after 12 weeks of DAA treatment [29]. Therapy was started the day of

transplantation. Interestingly, only 50% of the recipients seroconverted, becoming HCV Ab+. Vera and colleagues reviewed the outcome of 32 HCV-negative patients who received kidneys from HCV Ab+/NAT− donors. These patients were followed for an average of 10 months. Interestingly, 44% (14) of the patients seroconverted. None of the followed patients became viremic [30].

When to Treat

Post-transplant HCV recurrence is associated with the rapid development of graft cirrhosis in 20 to 40% of patients within 5 years from transplantation [31, 32]. Fifty percent of these patients will subsequently decompensate if left untreated [33]. The use of DAAs during the peri-transplant period is cost effective [34]. DAAs may improve the patient clinical status to the point where they can even be delisted. Belli and colleagues observed in their multicenter European study that 20% of their patients (21/103) with decompensated cirrhosis were delisted after 12 weeks of DAA therapy due to clinical improvement [35]. MELD scores decreased by ≥ 3 and albumin increased ≥ 0.5 g/dl. This was primarily seen in patients with low MELD scores < 16 (35%) compared with those with MELD scores > 20 (5%). Hence, those patients with mid- to high-MELD scores may not benefit and even unintentionally have to wait for a longer period of time for a transplant, as their MELD score may improve independently from their actual clinical status. This concept is known as the "MELD purgatory." Some organizations favor keeping the baseline MELD score after DAA therapy [36]. Further research is warranted to determine the role of pre-transplant DAA therapy in patients with higher MELD scores and renal disease.

The post-transplant period is considered 2–8 weeks after transplant. This timeframe is critical as it holds the highest risk for complications such as acute rejection, infections, renal failure, and hemorrhage [37]. In contrast, this period is of particular importance, as it is also known that during the immediate perioperative time, the HCV RNA level falls rapidly, offering an excellent window to treat HCV [32]. Levitsky and colleagues recently published data regarding post-transplant DAA therapy in HCV+ patients receiving HCV-liver allografts [38••]. The 16 studied patients were treated for a total of 4 weeks, starting therapy on the day of transplant. All patients achieved sustained virological response (SVR) except one who required 12 additional weeks of therapy due to NS5A resistance. The median MELD score was 13; patients with a GFR below 40 ml/min were excluded. Another study including HCV-viremic patients receiving HCV-viremic kidneys demonstrated that a 12-week DAA therapy was efficacious and safe. The median time of initiation of therapy was 119 days. The data regarding post HCV-viremic transplants is promising but limited, further research needs to be pursued in diverse populations, different DAAs, and advanced renal failure [39].

The Downside

With rapid emerging data, HCV-positive organs are starting to be considered for transplantation as relatively safe options. DAAs are new and there are still many questions to be answered [39]. HCV-positive organs may portend other complications that we have not yet seen.

A recent multicenter study suggested that DAA therapy might be related to immune-mediated graft dysfunction

Table 1 Pros and cons of therapy before and after liver or kidney transplant in HCV-viremic patients

Liver transplantation in HCV-viremic patients		
	Pre-transplant therapy	Post-transplant therapy
Pros	Improvement of clinical status for low MELD score patients—negating need for transplant	Shorter waitlist time
		Utilization of the immediate low virological post-transplant period for short duration of treatment with curative intent
Cons	MELD purgatory for patients that MELD does not correlate with clinical status	Uncertainty regarding DAA access and payment responsibility
	Patients may be hesitant to receive an HCV-viremic liver after being treated	Risk of resistant HCV transmission
	Patient will no longer be treatment-naive	DAA-related side effects and drug-drug interactions
		Risk of post-transplant complications that may preclude the timely initiation of DAA therapy
Kidney transplantation in HCV-viremic patients		
Pros	Decreased exposure to HCV	Increases the organ pool for transplantation
Cons	Limited available regimens due to low GFR	Risk of resistant HCV transmission

The pros of post-transplant therapy in *HCV-negative patients* are similar. The cons may also include hesitancy due to the perception that an HCV-viremic organ is of low quality.

(IGD), which was commonly seen with interferon therapy. The incidence of DAA IGD was 3.4% ($n = 978$) [40].

Table 1 summarizes the pros and cons of therapy before and after liver or kidney transplant in HCV-viremic patients. There are still some concerns regarding HCV Ab+/NAT− organs as a potential HCV transmission source. A small prospective study including 25 HCV Ab− or NAT− patients who received an HCV Ab+/NAT− liver demonstrated a HCV transmission rate of 16% ($n = 4$). All the donors from this group died from drug overdose. Three of these patients were successfully treated with DAAs; the other patient died of postoperative complications and was not treated [41]. The specific transmission mechanism is still unknown. Despite showing a high safety profile, DAAs are still relatively new medications that require further investigation in particular cohorts. It is already known that there are some mild side effects from DAA therapy like headache and nausea. There are also some drug-drug interactions, especially with regimens containing protease inhibitors.

Conclusion

Direct-acting antiviral therapy for hepatitis C virus infection is a major medical advancement. Since 2011, DAAs have cured millions of patients worldwide. The transplant community now has a new opportunity to offer more viable high-quality allografts for patients awaiting transplant. Careful determination of the hepatitis C virological organ status is key.

Some professional societies are starting to recognize HCV-viremic organs as a potential source for transplantation. However, there is considerable difference between the position to conduct research in this area under IRB oversight [12] and the clinical reality that these organs are being used in routine clinical practice. Continued efforts at clear reporting and preview of barriers such as access to DAA treatment for post-transplant infection are important. There are still many questions to be answered, but emerging data continue to be encouraging.

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Compliance with Ethical Standards

Conflict of Interest Hugo E. Vargas reports grants from Conatus Pharmaceuticals, grants from Malinkrodt, grants from Griffols, other from Transmedics, and other from American Journal of Gastroenterology, outside the submitted work. Blanca C. Lizaola-Mayo and David M. Chascsa each declare no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Schnitzler MA, Lentine KL, Burroughs TE. The cost effectiveness of deceased organ donation. Transplantation. 2005;80(11):1636–7.
2. Schnitzler MA, Whiting JF, Brennan DC, Lentine KL, Desai NM, Chapman W, et al. The life-years saved by a deceased organ donor. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2005;5(9):2289–96. https://doi.org/10.1111/j.1600-6143.2005.01021.x.
3. Kucirka LM, Singer AL, Ros RL, Montgomery RA, Dagher NN, Segev DL. Underutilization of hepatitis C-positive kidneys for hepatitis C-positive recipients. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2010;10(5):1238–46. https://doi.org/10.1111/j.1600-6143.2010.03091.x.
4. Habka D, Mann D, Landes R, Soto-Gutierrez A. Future economics of liver transplantation: a 20-year cost modeling forecast and the prospect of bioengineering autologous liver grafts. PLoS One. 2015;10(7):e0131764. https://doi.org/10.1371/journal.pone.0131764.
5. Gonzalez SA, Trotter JF. The rise of the opioid epidemic and hepatitis C-positive organs: a new era in liver transplantation. Hepatology. 2018;67(4):1600–8. https://doi.org/10.1002/hep.29572.
6. Durand CM, Bowring MG, Thomas AG, Kucirka LM, Massie AB, Cameron A, et al. The drug overdose epidemic and deceased-donor transplantation in the United States: a national registry study. Ann Intern Med. 2018;168(10):702–11. https://doi.org/10.7326/m17-2451.
7.• Axelrod DA, Schnitzler MA, Alhamad T, Gordon F, Bloom RD, Hess GP, et al. The impact of direct-acting antiviral agents on liver and kidney transplant costs and outcomes. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(10):2473–82. https://doi.org/10.1111/ajt.14895 **Important initial study, demonstrating that DAA therapy improves HCV-positive transplant outcomes.**
8. Mucke MM, Mucke VT, Lange CM, Zeuzem S. Managing hepatitis C in patients with the complications of cirrhosis. Liver int. 2018;38(Suppl 1):14–20. https://doi.org/10.1111/liv.13636.
9. Curry MP, O'Leary JG, Bzowej N, Muir AJ, Korenblat KM, Fenkel JM, et al. Sofosbuvir and Velpatasvir for HCV in patients with decompensated cirrhosis. N Engl J Med. 2015;373(27):2618–28. https://doi.org/10.1056/NEJMoa1512614.
10. Chascsa DM, Mousa OY, Pungpapong S, Zhang N, Chervenak A, Nidamanuri S, et al. Clinical outcomes of hepatitis C treatment before and after kidney transplantation and its impact on time to transplant: a multicenter study. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(10):2559–65. https://doi.org/10.1111/ajt.14931.
11. Trotter PB, Summers DM, Ushiro-Lumb I, Robb M, Bradley JA, Powell J, et al. Use of organs from hepatitis C virus-positive donors for uninfected recipients: a potential cost-effective approach to save lives? Transplantation. 2018;102(4):664–72. https://doi.org/10.1097/tp.0000000000002033.
12. Levitsky J, Formica RN, Bloom RD, Charlton M, Curry M, Friedewald J, et al. The American Society of Transplantation Consensus Conference on the use of hepatitis C viremic donors in solid organ transplantation. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2017;17(11):2790–802. https://doi.org/10.1111/ajt.14381.
13. Albertoni G, Castelo Girao MJ, Schor N. Mini review: current molecular methods for the detection and quantification of hepatitis B virus, hepatitis C virus, and human immunodeficiency virus type

1. Int J Infect Dis. 2014;25:145–9. https://doi.org/10.1016/j.ijid.2014.04.007.
14. Kaberg M, Naver G, Hammarberg A, Weiland O. Incidence and spontaneous clearance of hepatitis C virus (HCV) in people who inject drugs at the Stockholm Needle Exchange-importance for HCV elimination. J Viral Hepat. 2018;25(12):1452–61. https://doi.org/10.1111/jvh.12969.
15. Bowring MG, Kucirka LM, Massie AB, Luo X, Cameron A, Sulkowski M, et al. Changes in utilization and discard of hepatitis C-infected donor livers in the recent era. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2017;17(2):519–27. https://doi.org/10.1111/ajt.13976.
16. Lai JC, O'Leary JG, Trotter JF, Verna EC, Brown RS Jr, Stravitz RT, et al. Risk of advanced fibrosis with grafts from hepatitis C antibody-positive donors: a multicenter cohort study. Liver Transpl. 2012;18(5):532–8. https://doi.org/10.1002/lt.23396.
17. Vargas HE, Laskus T, Wang LF, Lee R, Radkowski M, Dodson F, et al. Outcome of liver transplantation in hepatitis C virus-infected patients who received hepatitis C virus-infected grafts. Gastroenterology. 1999;117(1):149–53.
18. Ballarin R, Cucchetti A, Spaggiari M, Montalti R, Di Benedetto F, Nadalin S, et al. Long-term follow-up and outcome of liver transplantation from anti-hepatitis C virus-positive donors: a European multicentric case-control study. Transplantation. 2011;91(11):1265–72. https://doi.org/10.1097/TP.0b013e318219eb8f.
19. Abbott KC, Bucci JR, Matsumoto CS, Swanson SJ, Agodoa LY, Holtzmuller KC, et al. Hepatitis C and renal transplantation in the era of modern immunosuppression. J Am Soc Nephrol. 2003;14(11):2908–18.
20. Singh N, Neidlinger N, Djamali A, Leverson G, Voss B, Sollinger HW, et al. The impact of hepatitis C virus donor and recipient status on long-term kidney transplant outcomes: University of Wisconsin experience. Clin Transpl. 2012;26(5):684–93. https://doi.org/10.1111/j.1399-0012.2011.01583.x.
21. Kim WR, Lake JR, Smith JM, Schladt DP, Skeans MA, Harper AM, et al. OPTN/SRTR 2016 annual data report: liver. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(Suppl 1):172–253. https://doi.org/10.1111/ajt.14559.
22. Northup PG, Intagliata NM, Shah NL, Pelletier SJ, Berg CL, Argo CK. Excess mortality on the liver transplant waiting list: unintended policy consequences and Model for End-Stage Liver Disease (MELD) inflation. Hepatology. 2015;61(1):285–91. https://doi.org/10.1002/hep.27283.
23. Iakova P, Awad SS, Timchenko NA. Aging reduces proliferative capacities of liver by switching pathways of C/EBPalpha growth arrest. Cell. 2003;113(4):495–506.
24. Ishak K, Baptista A, Bianchi L, Callea F, De Groote J, Gudat F, et al. Histological grading and staging of chronic hepatitis. J Hepatol. 1995;22(6):696–9.
25. Hart A, Smith JM, Skeans MA, Gustafson SK, Wilk AR, Robinson A, et al. OPTN/SRTR 2016 annual data report: kidney. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(Suppl 1):18–113. https://doi.org/10.1111/ajt.14557.
26. KDIGO clinical practice guidelines for the prevention, diagnosis, evaluation, and treatment of hepatitis C in chronic kidney disease. Kidney Int Suppl 2008(109):S1–99. doi:https://doi.org/10.1038/ki.2008.81.
27. Rao PS, Schaubel DE, Guidinger MK, Andreoni KA, Wolfe RA, Merion RM, et al. A comprehensive risk quantification score for deceased donor kidneys: the kidney donor risk index. Transplantation. 2009;88(2):231–6. https://doi.org/10.1097/TP.0b013e3181ac620b.
28.•• Sibulesky L, Kling CE, Blosser C, Johnson CK, Limaye AP, Bakthavatsalam R, et al. Are we underestimating the quality of aviremic hepatitis C-positive kidneys? Time to reconsider. American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant. Surgeons. 2018;18(10):2465–72. https://doi.org/10.1111/ajt.14701 **Strong data, recommending revision of the KDRI.**
29. Durand CM, Bowring MG, Brown DM, Chattergoon MA, Massaccesi G, Bair N, et al. Direct-acting antiviral prophylaxis in kidney transplantation from hepatitis C virus-infected donors to noninfected recipients: an open-label nonrandomized trial. Ann Intern Med. 2018;168(8):533–40. https://doi.org/10.7326/M17-2871.
30. de Vera ME, Volk ML, Ncube Z, Blais S, Robinson M, Allen N, et al. Transplantation of hepatitis C virus (HCV) antibody positive, nucleic acid test negative donor kidneys to HCV negative patients frequently results in seroconversion but not HCV viremia. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(10):2451–6. https://doi.org/10.1111/ajt.15031.
31. Konig V, Bauditz J, Lobeck H, Lusebrink R, Neuhaus P, Blumhardt G, et al. Hepatitis C virus reinfection in allografts after orthotopic liver transplantation. Hepatology. 1992;16(5):1137–43.
32. Garcia-Retortillo M, Forns X, Feliu A, Moitinho E, Costa J, Navasa M, et al. Hepatitis C virus kinetics during and immediately after liver transplantation. Hepatology. 2002;35(3):680–7. https://doi.org/10.1053/jhep.2002.31773.
33. Berenguer M, Ferrell L, Watson J, Prieto M, Kim M, Rayon M, et al. HCV-related fibrosis progression following liver transplantation: increase in recent years. J Hepatol. 2000;32(4):673–84.
34. Cortesi PA, Mantovani LG, Ciaccio A, Rota M, Mazzarelli C, Cesana G, et al. Cost-effectiveness of new direct-acting antivirals to prevent post-liver transplant recurrent hepatitis. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2015;15(7):1817–26. https://doi.org/10.1111/ajt.13320.
35. Belli LS, Berenguer M, Cortesi PA, Strazzabosco M, Rockenschaub SR, Martini S, et al. Delisting of liver transplant candidates with chronic hepatitis C after viral eradication: a European study. J Hepatol. 2016;65(3):524–31. https://doi.org/10.1016/j.jhep.2016.05.010.
36. Belli LS, Duvoux C, Berenguer M, Berg T, Coilly A, Colle I, et al. ELITA consensus statements on the use of DAAs in liver transplant candidates and recipients. J Hepatol. 2017;67(3):585–602. https://doi.org/10.1016/j.jhep.2017.03.006.
37. Jimenez-Perez M, Gonzalez-Grande R, Rando-Munoz FJ. Management of recurrent hepatitis C virus after liver transplantation. World J Gastroenterol. 2014;20(44):16409–17. https://doi.org/10.3748/wjg.v20.i44.16409.
38.•• Levitsky J, Verna EC, O'Leary JG, Bzowej NH, Moonka DK, Hyland RH, et al. Perioperative Ledipasvir-Sofosbuvir for HCV in liver-transplant recipients. N Engl J Med. 2016;375(21):2106–8. https://doi.org/10.1056/NEJMc1611829 **Important data proving efficacy of post-transplant DAA therapy in HCV+ patients receiving HCV-liver allografts.**
39. Berenguer M, Agarwal K, Burra P, Manns M, Samuel D. The road map toward an hepatitis C virus-free transplant population. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(10):2409–16. https://doi.org/10.1111/ajt.14976.
40. Chan C, Schiano T, Agudelo E, Paul Haydek J, Hoteit M, Laurito MP, et al. Immune-mediated graft dysfunction in liver transplant recipients with hepatitis C virus treated with direct-acting antiviral therapy. Am J Transplant Off J Am Soc Transplant Am Soc Transplant Surg. 2018;18(10):2506–12. https://doi.org/10.1111/ajt.15053.
41. Bari K, Luckett K, Kaiser T, Diwan T, Cuffy M, Schoech MR, et al. Hepatitis C transmission from seropositive, nonviremic donors to non-hepatitis C liver transplant recipients. Hepatology. 2018;67(5):1673–82. https://doi.org/10.1002/hep.29704.