Anesthetic and Perioperative Management of Adult Transplant Recipients in Nontransplant Surgery

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Each year, >16,000 patients receive whole organ transplants in the United States alone, and this number is expected to increase yearly (1). Because the 1-yr survival rate for most transplant recipients is approaching 80%–90% and continues to improve annually, an increasing number of patients who received a transplant present for either elective or emergency nontransplant surgery (2–4). Therefore, anesthesiologists and surgeons are often required to manage transplant recipients in hospitals that are not otherwise involved in transplantation procedures. The general considerations related to any transplant recipient are the physiological and pharmacological problems of allograft denervation, the side effects of immunosuppression, the risk of infection, and the potential for rejection.

Pharmacological Considerations in Transplant Recipients

Transplant recipients are always under various regimens of immunosuppression. The immunosuppressive drugs in common use are cyclosporine A, azathioprine, antilymphocyte globuline, monoclonal antibodies, and steroids. Newer drugs, such as tacrolimus (FK506), may replace cyclosporine A, and mycophenolate mofetil may replace azathioprine in some immunosuppression protocols (5).

Because cyclosporine or tacrolimus levels must be kept within the indicated therapeutic range, the blood levels of patients receiving these drugs should be monitored daily during the perioperative period. Clinically, significant reductions of cyclosporine or tacrolimus blood levels can be caused by dilution with massive fluid infusion perioperatively (6) and cardiopulmonary bypass (7). Cyclosporine and tacrolimus are metabolized in the liver through the cytochrome P-450 system. Therefore, many drugs administered during anesthesia or perioperatively may affect cyclosporine or tacrolimus blood levels (Table 1). All immunosuppressive drugs now in use have significant side effects that may have a direct impact on anesthetic and perioperative management (8) (Table 2). Drugs that may cause renal dysfunction when administered with cyclosporine or tacrolimus are presented in Table 3 (8). Generalized major motor seizures are a serious complication of cyclosporine or tacrolimus therapy. Because the seizure threshold of patients treated with these drugs may be lowered, hyperventilation during mechanical ventilation should be avoided (9,10). Hyperkalemia and hypomagnesemia may be observed with cyclosporine or tacrolimus therapy (11–13).

Azathioprine's major side effect is bone marrow suppression, and the drug dose may require adjustment for leucopenia or thrombocytopenia. Antithymocyte globuline (ATG) also may be responsible for thrombocytopenia. Drugs that may cause marrow toxicity when given to patients receiving azathioprine include allopurinol, angiotensin-converting enzyme inhibitors, sulfasalazine, and 5-amino salicilate acid (8).

Steroids are used for the prevention of rejection and for the treatment of acute rejection episodes. Despite intense effort to eliminate or replace them, steroids are still a mainstay of the posttransplant immunosuppression protocol, and their long-term use may result in steroid-related side effects (8).

Interactions Between Immunosuppressive and Anesthetic Drugs

Immunosuppressive drugs may modify the pharmacological behavior of many drugs used in anesthesia.

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Table 1. Drugs That Affect Cyclosporine and Tacrolimus Blood Levels

Increase blood levels	Decrease blood levels
Bromocryptine	Carbamazepine
Chloroquine[a]	Octreotide[a]
Cimetidine[b]	Phenobarbital
Clarithromycine	Phenytoin
Co-trimoxazole	Rifampycin
Danazole	Ticlopidine[a]
Diltiazeme	
Erytromycin	
Fluconazole	
Itraconazole	
Ketoconazole	
Metoclopramide	
Nicardipine	
Verapamil	

[a] Reported with cyclosporine; may not interact with tacrolimus.
[b] May not interact with cyclosporine.

Table 2. Side Effects of Immunosuppressives That Have a Direct Impact on Anesthetic and Perioperative Management

	CyA	Tacr	Aza	Ster	MMF	ATG	OKT3
Anemia	−	−	+	−	+	−	−
Leucopenia	−	−	+	−	+	+	+
Thrombocytopenia	−	−	+	−	+	−	−
Hypertension	++	+	−	+	−	−	−
Diabetes	+	++	−	++	−	−	−
Neurotoxicity	+	+	−	+	−	−	−
Renal insufficiency	+	++	−	−	−	−	−
Anaphylaxis	−	−	−	−	−	+	+
Fever	−	−	−	−	−	+	+

ATG = anti-thymocyte globulin, Aza = azathioprine, CyA = cyclosporine A, MMF = mycophenolate mofetil, OKT3 = monoclonal antibodies directed against CD-3 antigen of the surface of human T-lymphocytes, Ster = steroids, Tacr = tacrolimus (FK506).

Table 3. Drugs That May Cause Renal Dysfunction When Administered with Cyclosporine or Tacrolimus

Amphotericin	Co-trimoxazole
Cimetidine	Vancomycin
Ranitidine	Tobramycin
Melphanan	Gentamycin
Nonsteroidal antiinflammatory drugs	Tacrolimus or cyclosporine

There are few data concerning the interactions of cyclosporine or tacrolimus with anesthetics used for either transplant or nontransplant surgery. Data on the effects of general anesthesia on IV cyclosporine or tacrolimus pharmacokinetics in humans are also limited. In patients who received their oral cyclosporine dose <4 h preoperatively, subtherapeutic blood levels have been reported (14). This may be due to a reduction in gastric emptying and absorption from the proximal small bowel, which can occur during isoflurane anesthesia in the rat (15,16). Steady-state blood levels of cyclosporine and cyclosporine clearance in rabbits are not altered by isoflurane/nitrous oxide anesthesia (17). Propofol infusion does not modify the cyclosporine blood levels in humans (18). Cyclosporine tends to enhance pentobarbital anesthesia and fentanyl analgesia in mice, but the mechanism is unclear (19,20). Cyclosporine enhances the effects of muscle relaxants. Prolonged neuromuscular block after vecuronium and pancuronium administration in patients receiving cyclosporine has been described (21–24). Cyclosporine and, to a lesser degree, its solvent, cremophor, enhance the neuromuscular block induced by vecuronium and atracurium (25,26). Therefore, patients receiving cyclosporine as immunosuppressive therapy may require a smaller dose of nondepolarizing muscle relaxant, and the recovery time may be prolonged (27,28).

Clinically relevant doses of azathioprine do not antagonize neuromuscular blocking drugs in humans (9,24,29,30).

Anesthesia and Perioperative Care

Preoperative Assessment of Transplant Recipients

The preoperative assessment of transplant recipients undergoing nontransplant surgery should focus on graft function, rejection, presence of infection, and function of other organs, particularly those that may be compromised due to either immunosuppressive therapy or dysfunction of the transplanted organ.

Rejection results in a progressive deterioration in organ function tests, is the main cause of late mortality in the transplant recipients (5,31,32), and should be suspected if functional tests of the transplanted organ(s) are abnormal. The presence of rejection should always be ruled out preoperatively. There is some evidence that patients who undergo surgery during a period of rejection have higher morbidity (33).

The presence of an infection should also always be ruled out preoperatively. Infection is a significant cause of morbidity and mortality after transplantation (5,8,31,32,34). Immunosuppressed patients are at risk of infections that may be bacterial, viral, fungal, or protozoan (5,31,32,34). Immunosuppression undoubtedly plays a role in the development of infections. However, reducing the dose of immunosuppressive drugs in the perioperative period may increase the risk of rejection. It is imperative to realize that the immunosuppressed patient does not present the typical signs and symptoms of intraabdominal sepsis—fever, leucocytosis, and physical signs of peritonitis are often absent. A very high index of suspicion is required in view of reports citing a 4%–26% incidence of abdominal complications requiring surgery (34,35).

Renal function may be compromised because of immunosuppression therapy and should be assessed

in all transplant recipients. In therapeutic doses, cyclosporine and tacrolimus, may cause a dose-related decrease in renal blood flow and glomerular filtration rate, due to renal vasoconstriction. Both increase thromboxane A2, and perhaps endothelin production, and are thus responsible for many of the renal hemodynamic effects (36,37).

Upper gastrointestinal bleeding may be secondary to peptic ulcer disease, gastritis, or cytomegalovirus gastroenteritis (38). Hepatobiliary and pancreatic diseases are relatively common after transplantation (39–45).

General Anesthetic Considerations

A variety of anesthetic techniques (general, regional, neuroleptic) have been successfully used in patients with a transplant history.

Standard premedication may be used, as in nontransplant patients. The choice of perioperative monitoring techniques is determined by the type of surgery, the anesthesia planned, and the equipment available. Perioperative invasive monitoring requires fully aseptic techniques and should be discussed in terms of the risk-benefit ratio (9,27,33,39). Oral endotracheal intubation is preferred over nasal intubation because of the potential of infection caused by nasal flora (46). The use of a laryngeal mask is acceptable (47). Appropriate perioperative antibiotic prophylaxis should be used, just as in nontransplant patients (39,48). When hepatic and renal function is normal, there is no contraindication to the use of any anesthetic (9,27,33,39).

If an epidural or spinal technique is planned, clotting studies and platelet count should be normal. Patients taking azathioprine or antithymocyte globuline (ATG) may have thrombocytopenia, which increases the risks associated with central neural blockade (9,27,39). Azathioprine withdrawal in the perioperative period in patients taking warfarin may precipitate bleeding (49). Although the mechanism of this drug interaction is not established, it is possible that 6-mercaptopurine, the immediate metabolite of azthioprine, induces the hepatic microenzymes that metabolize warfarin.

Bupivacaine is a commonly used local anesthetic. Although decreased renal function may result in the risk of increased toxic effects, this does not seem to be an issue in clinical doses (33,50). Epidural administration of bupivacaine is not associated with higher plasma bupivacaine concentrations in kidney transplant recipients compared with nonuremic patients undergoing kidney surgery (51). Some transplant recipients who have undergone repeated surgery do seem to develop tolerance to opioids. Regimens should be titrated according to the clinical effect and the potential of side effects. Although the excretion of morphine is not affected by renal impairment, the metabolites morphine-3-glucuronide (M3G) and morphine-6-glucuronide (M6G) can accumulate and may be responsible for prolonged sedation postoperatively (52,53).

Nonsteroidal antiinflammatory drugs should be avoided because of the risk of adverse interactions (e.g., gastrointestinal hemorrhage, nephrotoxicity, hepatic dysfunction). They augment nephrotoxicity of cyclosporine, as both drugs affect the renal microcirculation, although the exact mechanism is unclear (54,55). Immunosuppressive therapy should be continued during the perioperative period, and daily monitoring of steady-state cyclosporine or tacrolimus blood levels is recommended. To maintain therapeutic blood levels, it is important to administer oral cyclosporine 4–7 h before surgery (14). The dose of other immunosuppressive drugs should not be altered perioperatively unless the route of administration needs to be changed from oral to IV. The oral dose of prednisone is equal to the IV methylprednisolone dose. Oral and IV doses of azathioprine are approximately equivalent (8,56). Supplemental "stress-coverage" steroids are probably not necessary, except in transplant recipients recently withdrawn from them (39,57,58).

Although the effect of transplantation and, in particular, of cyclosporine on intravascular coagulation is controversial (59,60), special consideration should be given to deep venous thrombosis prophylaxis in transplant recipients, particularly if other risk factors are present (39).

Severe perioperative airway obstruction may be caused by underlying posttransplant lymphoproliferative disease (61,62).

Specific Anesthetic Considerations

Kidney Transplant Recipients. The success of renal transplantation, especially in diabetic and elderly patients, is associated with an increase in the incidence and severity of cardiovascular disease in these populations (63,64). Recipients with adequately functioning kidney grafts may have creatinine levels within normal range. However, the glomerular filtration rate and effective renal plasma flow are likely to be significantly lower than those of healthy subjects, and the activity of drugs excreted from the kidney may be prolonged (9,64). Azotemia, proteinuria, and hypertension may indicate chronic rejection of the graft (65). Because variables of renal function are likely to be abnormal in kidney transplant recipients, it seems prudent to choose drugs that do not rely on the kidney for excretion (e.g., atracurium). Nephrotoxic drugs should be avoided. Diuretics should not be given without careful evaluation of the patient's volume status. Renal hypoperfusion from inadequate intravascular volume should be prevented (9,27,66–68).

Because of the high incidence of hypertension in this population, it is common for renal transplant recipients to receive oral antihypertensive therapy (68).

Patients with renal graft dysfunction who have been recently hemodialyzed may have hypovolemia and/or hypokalemia. Hypovolemia leads to cardiovascular instability, and hypokalemia causes cardiac arrhythmia and increased susceptibility to muscle relaxants (69).

Liver Transplant Recipients. After successful liver transplantation, tests of synthetic liver function are normal (31,66). In the immediate posttransplant period, there is a significant increase in all liver enzyme levels. However, the levels gradually decrease over the first 2 wk postoperatively as allograft function becomes normal. Recovery of drug metabolism capacity occurs immediately after reperfusion of the liver graft. Considerable metabolic capacity has been demonstrated by the liver grafts for morphine and midazolam (52,70). Renal dysfunction is common in liver transplant recipients, and renal excretion is an important pharmacological consideration for these patients (9,31,52).

Liver transplantation results in reversal of the hyperdynamic state that characterizes patients with end-stage liver disease, and cardiac performance improves in the months after transplantation.

Pulmonary dysfunction in patients with end-stage liver disease may result from (a) intrapulmonary shunting caused by intrapulmonary vascular dilatation; (b) ventilation/perfusion mismatch caused by pleural effusions, ascites, and diaphragm dysfunction and increased closing capacities; (c) diffusion abnormalities caused by interstitial pneumonitis and/or pulmonary hypertension; and (d) impaired hypoxic pulmonary vasoconstriction. Noncardiogenic pulmonary edema may be present in patients with fulminant hepatic failure. Very little is known about the biochemical relationship between hepatic dysfunction and subsequent pulmonary manifestations (71,72).

After successful liver transplantation, oxygenation improves in most patients. Hypoxemia caused by ventilation/perfusion mismatch is reversed over the course of the first postoperative months. Patients with preexisting true shunts may require more time to achieve reversal of hypoxemia, or hypoxemia may not resolve at all (71,72).

Normal physiological mechanisms that protect liver blood flow are blunted after liver transplantation (9). The liver is normally an important source of blood volume in shock states via a vasoconstrictive response, and this mechanism may be impaired after liver transplantation (73).

In liver transplant recipients, there is no evidence of increased risk of developing hepatitis after the administration of inhaled anesthetics (27).

Once vascular complications, such as hepatic artery thrombosis, occur, the mortality rate is high in this transplant population (74). Hepatic arterial thrombosis has been retrospectively associated with overtransfusion of blood products leading to hemoconcentration. Therefore, liver transplant recipients should have minimal blood viscosity (hematocrit approximately 28%) during the perioperative period (75).

Heart Transplant Recipients. After successful heart transplantation, most recipients return to New York Heart Association (NYHA) class I functional capacity (76–85).

The transplanted heart has no sympathetic, parasympathetic, or sensory enervation, and the loss of vagal influence results in a higher than normal resting heart rate (91–101 bpm). Unpredictable reenervation may occur after heart transplantation. There are two P waves on the electrocardiogram (ECG) after heart transplantation. The native pacemaker remains intact in cases in which a cuff of atria is left to permit surgical anastomosis to the grafted heart. Because the native P wave cannot traverse the suture line, it has no influence on the chronotropic activity of the transplanted heart. Intrinsic mechanisms and coronary autoregulation remain intact after heart transplantation. Carotid sinus massage and the Valsalva maneuver have no effect on the heart rate (27,32). Other effects associated with heart denervation include loss of cardiac baroreflexes and loss of sympathetic response to laryngoscopy and tracheal intubation (86). The denervated heart may have a more blunted heart rate response to inadequate anesthetic depth or analgesia (27).

Chronic allograft rejection usually presents as accelerated coronary artery disease. Therefore, heart transplant recipients may have significant myocardial ischemia without any clinical symptoms of pain. Although mild rejection does not compromise cardiac contractility, severe rejection can lead to significant systolic and diastolic dysfunction (87). The clinical picture of rejection usually includes fatigue, ventricular dysrhythmias, congestive heart failure, silent myocardial infarction on the ECG, and even sudden death (88).

Because heart denervation has important implications for the pharmacology of many drugs often used in the perioperative period, the anesthetic and therapeutic plan must take these differences into account. In the denervated heart, the catecholamine response is different from that in the normal heart because intact sympathetic nerves are required for the normal uptake and metabolism of catecholamines. Receptor density, however, seems to be unchanged, and the transplanted heart can respond to direct-acting drugs (e.g., sympathomimetics). Epinephrine and norepinephrine have an augmented inotropic effect in heart transplant recipients. In addition, both tend to have a higher β to α or inotropic to vasoconstrictor ratio. Dopamine acts predominantly by the release of norepinephrine and,

consequently, is a less effective inotrope in the denervated heart, having primarily dopaminergic and α effects (89). Isoproterenol and dobutamine have similar effects in both denervated and normal hearts. Therefore, they are both effective inotropes in the denervated heart. They increase myocardial contractility more than dopamine. Indirectly acting drugs, such as ephedrine, have blunted responses on blood pressure and heart rate in heart transplant recipients. Because vagolytic drugs, such as atropine, are ineffective in increasing heart rate, other positive chronotropic drugs, e.g., ephedrine and isoproterenol, should be readily available. Neostigmine usually has no effect on heart rate in the denervated heart. The use of monoamine oxidase inhibitors (MAO) most likely poses the same risk to the anesthetized patient with or without a transplanted heart (9). Pancuronium has no hemodynamic effects on the denervated heart, although it has normal systemic effects (9). Heart transplant recipients may present with ongoing rejection with myocardial dysfunction, accelerated coronary atherosclerosis, or severe dysrrhythmias, all of which must be diagnosed before surgery.

All preoperative drug therapy should be continued during the perioperative period. If a pacemaker is in place, its proper function should be confirmed. Central venous pressure monitoring or the placement of a pulmonary arterial catheter is not usually indicated for short, minor surgical procedures. However, because heart transplant recipients are preload-dependent and may be prone to myocardial dysfunction and/or ischemia, invasive hemodynamic monitoring is extremely useful during surgery that involves large volume shifts. There is a role for transesophageal echocardiography in addition to, or instead of, invasive hemodynamic monitoring in heart transplant recipients. General anesthesia is usually preferred, as there is a possibility of impaired response to hypotension after spinal or epidural anesthesia. A goal of anesthesia in this setting is the avoidance of significant vasodilation and acute decrease of the preload (69,77,78,85,90). Although inhaled general anesthetics have well known myocardial depressant properties, they are generally well tolerated unless there is significant heart failure (9,27,76–85).

Lung and Heart-Lung Transplant Recipients. Denervation of the lung seems to have a limited effect on the pattern of breathing. Bronchial hyperresponsiveness causing bronchoconstriction is common. Denervation ablates afferent sensation below the level of the tracheal anastomosis, and patients with a tracheal anastomosis lose the cough reflex and are more prone to retention of secretions and silent aspiration (32). Response to CO_2 rebreathing is normal in these patients (91).

If rejection occurs, forced expiratory volume, vital capacity, and total lung capacity may decrease significantly, and arterial blood gas analysis may show an increased alveolar to arterial oxygen gradient. Obliterative bronchiolitis is thought to be due to chronic rejection, and it usually occurs after the third month posttransplantation (92). Symptoms can mimic an upper respiratory tract infection and include fever, leucopenia, hypoxemia, fatigue, and shortness of breath. Chest radiography shows perihilar infiltration or opacification of the graft. Pulmonary function testing shows obstructive defect (93,94).

Because transplanted lungs may have ongoing rejection that can adversely affect pulmonary function, patients should undergo spirometry before surgery (95–97). It is very difficult to differentiate between chronic rejection and infection. If allograft rejection or infection is suspected in these recipients of lung transplants, elective surgery should be postponed, and appropriate investigations should be performed (27).

Because lung transplant recipients lack a cough reflex below the tracheal anastomosis level, they are unable to clear secretions unless they are awake (27,32,85). In light of an abolished cough reflex, the potential bronchoconstriction, and the increased risk of chest infection, it can be argued that a regional anesthesia technique would be preferable to a technique that requires tracheal intubation (90,95–98). Because the disruption of the lymphatic drainage in the transplanted lung may cause interstitial fluid accumulation, particularly in the early posttransplantation period, it has been recommended that these patients be treated with diuretics and limited crystalloid infusion (9,27,32,85,90,96–98). In heart-lung transplant recipients, fluid management can be a problem because the heart requires adequate preload to maintain cardiac output and the lungs may have a lower threshold for developing pulmonary edema. Therefore, invasive hemodynamic monitoring is more often required in these patients (9).

Pancreas Transplant Recipients. Pancreatic transplantation is quite effective in restoring normal glucose metabolism, and pancreas transplant recipients do not require insulin to compensate for the stress response to surgery (99,100).

Some patients with urinary bladder-drained pancreatic grafts may suffer from chronic dysuria because of the presence of amylase in urine (99). Pancreatic ductal cells also secrete significant amounts of bicarbonate and water. Bicarbonate loss in the urine may cause dehydration or metabolic acidosis (101). Urinary amylase levels are used for monitoring pancreatic graft function (102).

Because the long-term effect of pancreas transplantation on diabetes-induced cardiovascular disease is not known, it is prudent to manage these patients with the assumption that they have coronary artery disease (103–105).

The effect of anesthesia on the catecholamine/glucagone response to hypoglycemia after pancreas

transplantation has not been specifically studied, and there are no formal recommendations for the perioperative management of glucose in pancreas transplant recipients with normal glucose metabolism (9,90).

In patients with failed pancreatic grafts, perioperative management of glucose levels and acid-base status is the same as that for any diabetic patient (106,107). Bicarbonate requirement should be assessed, especially in these patients with urinary bladder drainage of pancreatic secretions (99–101,108–111).

Intestinal Transplant Recipients. Three different types of intestinal transplantation can be performed depending on the cause and severity of intestinal failure and the presence of extraenteric organ dysfunction: isolated intestinal transplantation, transplantation of combined intestine and liver graft, or multivisceral transplantation (112).

Denervation and lymphatic dysfunction of the intestine affect intestinal permeability and absorption during the immediate posttransplantation period. If the intestinal mucosa barrier is damaged by ischemia, rejection, or enteritis, bacteria translocate into the bloodstream, and infections are often observed (113).

Because of the chronic use of total parenteral nutrition, venous access is usually difficult in intestinal transplant recipients. Some of these patients develop diarrhea and lose weight in the early posttransplantation period. Electrolyte requirements should be closely monitored (112,113).

Special Cases

Laparoscopic Surgery

The number of minimally invasive surgical procedures performed in transplant recipients is constantly increasing.

Lymphoceles can be successfully treated surgically after kidney transplantation by laparoscopy under general anesthesia (114–117). Laparoscopic cholecystectomy is as safe in the transplant population as in the general population. Despite a slightly higher rate of conversion to an open procedure (27% in transplant recipients versus 11% in the general population), the advantages of a short hospital stay, maintenance of oral immunosuppression, low morbidity, and early return to preoperative routines are equivalent (118,119).

Trauma

Transplant recipients sustaining trauma should receive the same initial resuscitation as any trauma victim. Graft dysfunction secondary to organ damage must be excluded (4). Only a few small series of traumatized transplant recipients have been reported. At the University of Arkansas, 12 transplant recipients with significant trauma were retrospectively identified over 40 months. The most common causes of trauma were car accidents and falls. All patients suffered closed skeletal fractures, and no transplanted organ was directly injured or lost. Complications included death, deep venous thrombosis, renal failure, pneumonia, and sepsis. Despite immunosuppression and preexisting renal osteodystrophy, fractures healed well in the surviving patients (4). Direct blunt trauma to the transplanted kidney parenchyma may present immediately with massive hemorrhage or insidiously as graft dysfunction (39,120).

It is generally assumed that immunosuppressed patients are more susceptible to the effects of soft tissue damage and poor bone healing. Bone loss associated with renal, liver, or heart transplantation is a serious problem for most transplant recipients (4,121,122). Bone loss due to transplantation could enhance the risk of vertebral fractures, which occur mainly in the first year after transplantation (122).

Pregnancy

Advances in transplantation medicine present a unique challenge: female organ transplant recipients are able to carry pregnancies successfully. Pregnancy is possible without adversely affecting allograft survival (123–133).

Maternal side effects of immunosuppression therapy include nephrotoxicity and hepatotoxicity. All immunosuppressive drugs cross the placenta. Using immunosuppressants during the first trimester is not strongly associated with an increased risk of congenital anomalies; during the second and third trimesters, these drugs affect the fetus' immune system, and the result is a transiently compromised immune system and an increased risk of slightly lower birth weight, and other toxic effects of the infant's pancreas, liver, and lymphocytes (134–137). Current immunosuppressant drugs are not thought to be teratogenic (137), and their use cannot be discontinued during pregnancy (134–137). Pregnancy in patients with renal allografts can lead to a substantial decrease in cyclosporine blood levels (127).

In kidney, heart, or heart-lung transplant recipients, the rate of complications, such as preeclampsia, premature labor, and risk of acute allograft rejection postpartum, is higher than that in the nontransplant population (123–126,138–144). Compared with reports of previous immunosuppression regimens, pregnancy in women with liver transplants who were receiving tacrolimus was associated with a lower incidence of hypertension and preeclampsia but with a similar rate of preterm deliveries, low birth weight, and spontaneously resolving renal impairment of the infant (128). Renal dysfunction is the primary determinant of adverse pregnancy

outcomes in liver transplant recipients (132). A few pregnancies by recipients of pancreas or combined renal-pancreas transplants have been reported. In these patients, a long-standing history of insulin-dependent diabetes mellitus can result in multiple organ damage and increased risk of adverse outcome. Success of the pregnancy in these patients depends heavily on adequate multidisciplinary, specialized medical care (145–147).

Conclusions

In conclusion, transplant recipients have considerable medical, physiological, and pharmacological problems; therefore, a clear understanding of the physiology of the transplanted organ, the pharmacology of the immunosuppressive drugs, and the underlying surgical conditions is essential for these patients to safely undergo anesthesia and surgery. Local, regional, or general anesthesia can be safely delivered to transplant recipients, and a successful anesthetic and perioperative management can be provided.

Many of the perioperative problems in the transplant population have not been specifically studied, and there are no formal recommendations for their management. A registry for the perioperative problems of previously transplanted patients requiring other elective or emergency surgery is needed to formulate appropriate management and follow-up guidelines.

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