Table 4. Suggested Laboratory Thresholds for Performance of a Procedure in Patients with Chronic Liver Disease (52)

Procedure Risk	INR*	Platelet Count ($\times 10^9$/L)†	Fibrinogen (mg/dL)‡
Low	NA	> 20	> 100
High	< 2.5	> 30	> 100

Note–The suggested laboratory thresholds and strategies for correction are based on expert opinion (52). The addition of a fibrinogen level to laboratory testing for patients with chronic liver disease who plan to undergo a procedure may be helpful. INR = International Normalized Ratio; NA = not applicable.
*Recommendation: give 10 mg slow intravenous infusion of vitamin K if INR > 2.5.
†Recommendation: administer a dose of platelets in patients with a large spleen if platelet count is below suggested thresholds.
‡Recommendation: administer 1 dose (body weight < 80 kg) or 2 doses (body weight > 80 kg) of cryoprecipitate.

in cases of INR > 1.5 (89). In the absence of clear consensus, the AASLD 2009 position paper on liver biopsy (91) concluded that there is "no specific PT-INR and/or platelet count cutoff at or above which potentially adverse bleeding can be reliably predicted" and that "the decision to perform liver biopsy in the setting of abnormal laboratory parameters of hemostasis should continue to be reached as the results of local practice(s)."

Although PT/INR and platelet count have been shown to be poorly predictive of bleeding risk in patients with chronic liver disease, hyperfibrinolysis as a cause for bleeding is an emerging concept (52), and the assessment of fibrinogen levels in patients with chronic liver disease undergoing procedures may be of value. The AASLD cautions that the presence of hyperfibrinolysis (3-dimensional ecchymosis/hematoma) or clinically evident disseminated intravascular coagulation should preclude an invasive procedure (91). Given that these observations have yet to be validated in large-scale clinical trials and that there are no societal practice statements on this particular patient population, transfusion strategies for the management of patients with chronic liver disease are currently based on expert opinion. Table 4 summarizes the current expert consensus view in regard to prophylaxis and treatment recommendations for patients with chronic liver disease who undergo invasive procedures. Interventional radiologists are encouraged to engage hepatologists, hematologists, and transfusion medicine specialists in determining whether specific practice suggestions as outlined in Table 4 may be pertinent for their institution.

Recommendation 4: Because of rebalanced hemostasis in patients with chronic liver disease, the transfusion of plasma and platelets should be used judiciously given the potential for increased portal pressure and transfusion-related adverse events. It is likely that future research will result in specific laboratory parameters for patients with chronic liver disease to guide the use of blood products in this patient population. For patients with chronic liver disease undergoing an invasive procedure, consider adjusting INR and platelet count thresholds higher and lower, respectively, than in the general population to minimize unnecessary transfusions. Measuring fibrinogen level may be useful, with replacement with cryoprecipitate if the level is low (Table 4). (Level of evidence, E; strength of recommendation, weak.)

BLOOD COMPONENTS AND OTHER HEMOSTATIC AGENTS USED IN TRANSFUSION MANAGEMENT

The administration of blood components, such as red blood cells, plasma, platelets, cryoprecipitate, and other plasma derivatives, may be necessary to correct for coagulopathies in the periprocedural setting. Our knowledge regarding the impact of transfusion of plasma or platelets in the periprocedural setting is equivocal and is derived from small observational studies, retrospective case reviews, and consensus data (58,95–101). An exhaustive review of individual blood components and their mechanisms of action is beyond the scope of this paper; however, the properties of commonly used blood products are summarized in Table 5 (102). A discussion of the risks versus benefits of the transfusion of blood components is required for the patient to give informed consent. Some patients may refuse blood products for religious or nonreligious reasons.

Jehovah's Witness patients may not accept any blood components or may accept certain products such as plasma, cryoprecipitate, albumin, or plasma-derived factor concentrates (eg, prothrombin complex concentrate or fibrinogen concentrate). It is essential to document the patient's preferences in the medical records. Intravenous vitamin K can be used to correct preprocedural prolonged PT/INR as a result of vitamin K deficiency or VKA anticoagulation. In a Jehovah's Witness patient experiencing bleeding, some of the hemostatic options that could be used include recombinant factor VIIa (20 μg/kg every 2–4 h), desmopressin, or 4-factor prothrombin complex concentrate (103,104). Desmopressin (1-deamino-8-D-arginine vasopressin) is a synthetic analogue of antidiuretic hormone and enhances the plasma levels of factor VIII and von Willebrand factor (105). A single dose, 0.3 μg/kg diluted in 100 mL normal saline solution and infused intravenously over 20–30 minutes every 12 hours (maximum 6 doses), is expected to increase the factor VIII and von Willebrand factor levels by 3–6 fold. In addition, desmopressin may be indicated before image-guided procedures in patients with mild hemophilia A or type 1 von Willebrand disease (105,106) or in patients with congenital or acquired platelet disorders as a result of uremia or antiplatelet agents (106,107).

Very serious transfusion-related complications are known to arise, such as allergic reactions, nonhemolytic febrile reactions, acute hemolytic reactions, sepsis from bacterial contamination, transfusion-related acute lung injury, and transfusion-associated circulatory (ie, volume) overload (108). Packed red blood cells and platelets are often leukoreduced before storage to avoid adverse effects of white blood cells, including cytokine-induced nonhemolytic febrile reactions, cytomegalovirus, or alloimmunization to human leukocyte antigens. However, fatal graft-versus-host disease is preventable only by irradiation of these blood products for immunocompromised (not immunosuppressed) patients. Transfusion-associated circulatory overload, which can cause death, is the most common adverse effect of plasma transfusion and is often underrecognized and underreported (109). Because of its high protein content, plasma has a very high oncotic pressure and draws water from extravascular space into the circulatory system, and can therefore increase portal pressure rapidly, which may lead to adverse outcomes, particularly in patients with cirrhosis. These potential adverse events should be considered before administration of any blood products.

MANAGEMENT OF ANTICOAGULATION AND/OR ANITPLATELET AGENTS BEFORE AND AFTER A PROCEDURE

Timing of Anticoagulation and/or Antiplatelet Agent Withholding before a Procedure

Determining whether to hold anticoagulation and/or antiplatelet agents before a procedure, and the duration of the hold, depend on the patient's overall clinical status, including thrombotic and bleeding risks; on procedural bleeding risk; and on the pharmacologic characteristics of the medication being held (Figs 1–3). The goal of holding anticoagulation and/or antiplatelet agents before a procedure is to minimize medication-related bleeding complications, but also carries a theoretical risk for thrombosis as a result of undertreatment. Therefore, the timing of withholding of medications is a balance between patient thrombosis risk and procedural bleeding risk. Patient comorbidities (eg, renal function) should be taken into account, and, for patients who present with complex medical comorbidities, multidisciplinary shared decision-making with the patient's cardiovascular specialist or hematologist is recommended for the management of antithrombotic agents, including bridging options, in the periprocedural period. Table 6 (32–34,36,110–128) summarizes agent-specific recommendations for periprocedural medication interruption and reinitiation, including recommendations for patients with renal impairment (39,43,129–137). The recommendations are extrapolated from a compilation of expert consensus recommendations from the cardiology, anesthesia, interventional, and surgical literature