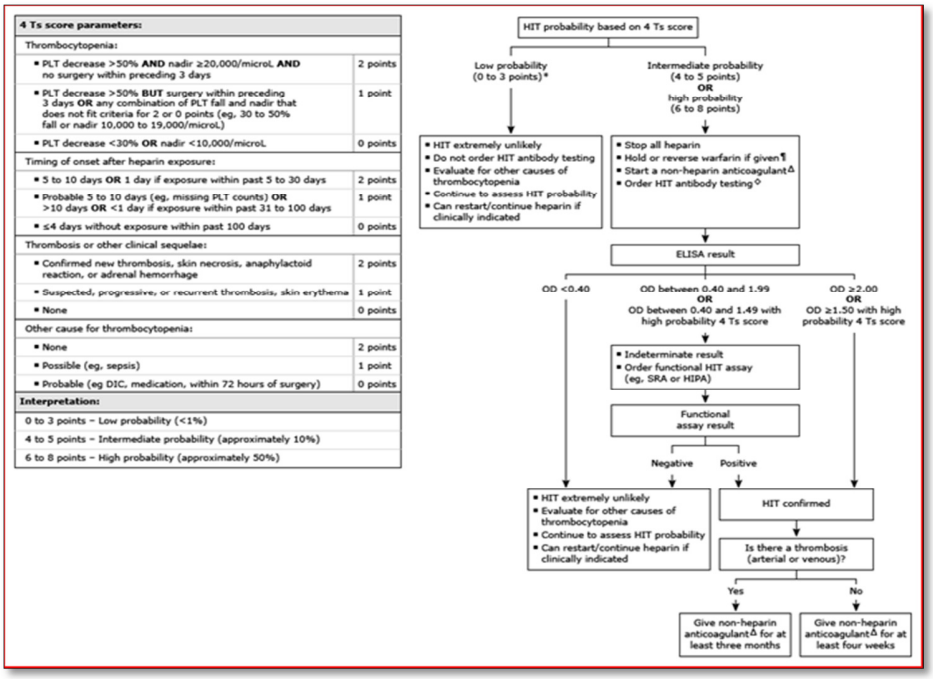

4 Ts score parameters:	
Thrombocytopenia:	
▪ PLT decrease >50% **AND** nadir ≥20,000/microL **AND** no surgery within preceding 3 days	2 points
▪ PLT decrease >50% **BUT** surgery within preceding 3 days **OR** any combination of PLT fall and nadir that does not fit criteria for 2 or 0 points (eg, 30 to 50% fall or nadir 10,000 to 19,000/microL)	1 point
▪ PLT decrease <30% **OR** nadir <10,000/microL	0 points
Timing of onset after heparin exposure:	
▪ 5 to 10 days **OR** 1 day if exposure within past 5 to 30 days	2 points
▪ Probable 5 to 10 days (eg, missing PLT counts) **OR** >10 days **OR** <1 day if exposure within past 31 to 100 days	1 point
▪ ≤4 days without exposure within past 100 days	0 points
Thrombosis or other clinical sequelae:	
▪ Confirmed new thrombosis, skin necrosis, anaphylactoid reaction, or adrenal hemorrhage	2 points
▪ Suspected, progressive, or recurrent thrombosis, skin erythema	1 point
▪ None	0 points
Other cause for thrombocytopenia:	
▪ None	2 points
▪ Possible (eg, sepsis)	1 point
▪ Probable (eg DIC, medication, within 72 hours of surgery)	0 points
Interpretation:	
0 to 3 points – Low probability (<1%)	
4 to 5 points – Intermediate probability (approximately 10%)	
6 to 8 points – High probability (approximately 50%)	

Figure 2. The 4 T's Score and diagnostic tree.

Source: Up to date, http://www.utdol.com

One of the prospective studies showed that the 4Ts score calculation, due to operator inexperience, resulted in misclassification in ~2% of cases [28] Patients with intermediate and high 4T score should have further laboratory test to confirm the diagnosis of HIT [12].

HIT expert probability score

It is described by Cuker, uses eight clinical features and an expert opinion for diagnosis of HIT. It demonstrated improved correlation between the serologic HIT testing and inter-observer agreement; it required a prospective validation [29].

Lillo-Le Louët model score

This scoring is used only for the post-cardiopulmonary bypass patients, scoring points are based on timing, duration of thrombocytopenia and the duration of cardiopulmonary bypass [30].

Laboratory tests

For the diagnosis of HIT it is necessary to have presence of anti-PF4/heparin antibodies in patient's serum, or activation of platelets by either functional or immunoassay.

Functional or platelet activation assays

The commonly used are 14C-SRA, platelet aggregation, and recently flow-based platelet activation assays detect antibodies capable of binding and cross-linking platelet. These functional assays are specific but not sensitive. The Specificity is more than 95% with PPVs of 89% to 100% and a low sensitivity of 56% to 100%. These assays are technically difficult to perform and available only in few medical centers [31].

Immunoassay

In contrast the immunoassays measure the presence of anti-PF4/heparin antibodies using enzyme-linked immunosorbent assay, particle gel or immune-turbid metric. The advantages of immunoassays are technically simple and highly sensitive (>99%), but lower specificity of 30 to 70% in the diagnosis of HIT [32].

DIFFERENTIAL DIAGNOSIS

HIT should be differentiated from disseminated intravascular coagulation (DIC), heparin toxicity and hyper-responsive thrombocytopenia. It is important to differentiate these clinical entities from HIT as their management is different from that of HIT. DIC is the activation of intravascular coagulation leading to thrombocytopenia, bleeding occurs in diseases ranging from sepsis to trauma and obstetrics. It is differentiated from HIT by prolonged coagulation parameters with elevated fibrinogen degradation products [33].

In acute heparin toxicity there is overdose of heparin, it can be fatal. Commonly manifested as wound bleeding, oozing mucosal membrane and in more severe case intraventricular hemorrhage. It is differentiated from HIT by abnormal activated prothrombin time and thrombocytopenia [34]. In hyper-responsive thrombocytopenia platelets are actively involved and consumed, seen in acute bronchial asthma

patients leading to bronchoconstriction with airway inflammation and thrombocytopenia. It can be differentiated from HIT by the signs and symptoms of primary disease causing hyperactive response [35].

COMPLICATIONS

The more frequently seen complications in HIT patients are venous/arterial thrombosis, skin lesions and acute platelet activation syndrome.

Venous thromboembolic complications are four times common than arterial thrombosis. The thrombosis mainly occurs in the larger vein, bilateral deep venous thrombosis and pulmonary embolism. Rarely can it cause thrombotic stroke, adrenal hemorrhagic infarction or cerebral venous sinus thrombosis. Arterial thrombosis can cause myocardial or brain infarction [36]. Skin necrosis or/and erythematous plaques occur at the site of heparin injections. Acute platelet activation syndrome in HIT patients will manifest by an acute inflammatory response with fever and chills. In spite of the severe thrombocytopenia the hemorrhagic complications occurs in around 6% HIT patients [37].

Management

To simplify we will discuss the HIT management in following subheadings:

Immediate interventions: These patients need immediate treatment for reduction of the risk of life-threatening thrombosis. The treatment should be started based on a strong clinical suspicion of HIT and on an intermediate or high probability 4 T's score while the laboratory test results are awaited. These initial interventions are discontinuation of all heparin, reversal of warfarin and initiation of a non-heparin anticoagulant. Two major goals of these interventions are to halt platelet activation as early as possible and to provide therapeutic anticoagulation with a non-heparin-anticoagulant to reduce the risk of thrombosis.

Heparin alternative

HIT patients stopping heparin alone will not be sufficient as these patients remain at risk for subsequent thrombosis. Anticoagulation is required in HIT patients having essential procedures or emergencies, acute coronary syndrome and thromboembolic phenomenon. Alternative anticoagulant should be free from generating HIT antibodies or cross-react with anti-heparin-platelet factor 4 antibodies. Vital aspects of selection of these alternative anticoagulant agents are familiarity, safety with efficacy, patient's organ functions, clearance of agents, the urgency of anticoagulation, need for reversal and the monitoring techniques [38].

Heparin alternatives available are direct thrombin inhibitors, which directly inhibit thrombin generation (argatroban, bivalirudin), selective factor X inhibitors (danaparoid, Fondaparinux) and the vitamin K antagonist warfarin or direct oral anticoagulants (DOACs) apixaban, edoxaban, rivaroxaban or dabigatran.

TREATMENT

In HIT patients the higher risk of thrombosis is from the time of diagnosis of HIT to the starting of alternative anticoagulation agents. Hence the management of HIT patient should be started without delay and waiting for the results of confirmatory laboratory tests [39]. The management of HIT patients is summarized by 6 "A"s [40].

1) Avoid and stop all heparin (any form, any route, heparin flush or heparinized catheters).
2) Administer direct thrombin inhibitors (alternative anticoagulation).
3) Anti-PF4/heparin antibody test for confirmation of diagnosis.
4) Avoid platelet transfusion.
5) Await platelet recovery.
6) Assess lower extremity thrombosis.

LMWHs (Low molecular weight heparin) are contraindicated in patients with HIT due to their cross-reaction with heparin antibodies, and in acute phase of HIT warfarin is contraindicated as it paradoxically worsens the thrombosis due to a drastic decrease in protein C levels [41]. Warfarin can be used only after the alternative anticoagulation and platelet count improves to more than 150,000/uL.

Choice of anticoagulation

Urgency of anticoagulation: In patients with an acute thrombosis, a parenteral agent is required to achieve the therapeutic anticoagulation as early as possible, by argatroban, bivalirudin, danaparoid or a DOAC (direct oral anticoagulant).

Urgent reversal possibilities: For patients requiring invasive procedure or those with higher risk for bleeding, we have to use an anticoagulant agent which can be reversed quickly. In these patients either argatroban or bivalirudin are the choice as they have a short half-lives and effects will be vanished within 1 h following discontinuation if they have no organ dysfunction.

Renal impairment/failure: In these patients commonly argatroban is used in the therapeutic doses, when platelet counts are stabilized, warfarin can be used, with close monitoring. Rivaroxaban and apixaban can be used in patients with end-stage renal failure and atrial fibrillation.

Hepatic impairment/failure: In these patients danaparoid, fondaparinux or bivalirudin in therapeutic doses are the drug of choice. The DOACs can be used in mild hepatic insufficiency and not advisable in moderate to severe liver disease.

Both renal and hepatic insufficiency: In this group of patients argatroban or bivalirudin is used at reduced dosages. When patient is stably anticoagulated can be shifted to warfarin. Apixaban is increasingly used in patients with renal impairments.

Other considerations: The local availability, institutional or/and clinician familiarity/preference and cost should be considered while selecting the anticoagulation in HIT patients. Patients cannot be on an intravenous agent, fondaparinux or one of the DOACs may be used and patients who cannot take an oral agent, fondaparinux or direct thrombin inhibitors are the anticoagulation of choice. These patients with HIT require therapeutic rather than prophylactic dosing, with the exception of patients with combined renal and hepatic impairment.

Duration of anticoagulation therapy: It's based on concurrence of thrombosis. The American and British guidelines recommend therapeutic dose anticoagulation for 4 weeks in patients with isolated HIT and up to 3 months for HIT patients with thrombosis [42,43].

PHARMACOLOGY OF ALTERNATIVE ANTICOAGULATION

DTI (Direct Thrombin Inhibitors)

DTI are the medications of choice in patients with HIT. These agents neither interact with heparin-dependent antibodies nor need an anti-thrombin as a cofactor. DTI have a predictable anticoagulant effect. They rapidly stop the thrombin storm and prevent new thrombus formation.

The DTI are argatroban, lepirudin, desirudin, bivalirudin, melagatran, and ximelagatran. Last 2 medications are no more available in the market. As per the structural configuration DTI are divided into 2 groups.

Divalent DTI: lepirudin and desirudin are 65-amino acid, polypeptides; the amino terminal binds to the catalytic site whereas carboxyl terminal irreversibly binds to the exosite of thrombin. Bivalirudin is a 20-amino acid derivative of hirudin, the peptide bond slowly cleaved from the catalytic site on thrombin; hence it is a reversible inhibitor of thrombin with shorter half-life. Lepirudin and desirudin are given by intravenous and subcutaneous routes, and half-life is 60 and 120 min, respectively, both of them are excreted through the renal system, hence requires dose adjustment in renal insufficiency patients. The initial loading dose is 0.4 mg/kg, then 0.15 mg/kg/h. Bivalirudin is given intravenously, largely cleared by peptidase but 20% is excreted through the kidneys, and needs dose adjustment in patients with renal impairment [44]. Patients receiving lepirudin should be monitored 4 h after the initiation of therapy and the target activated partial thromboplastin time (aPTT) should be 1.5-2.5 times , Desirudin does not need monitoring except in patients with renal impairment. Bivalirudin should be monitored by activated clotting time (ACT) in patients with renal insufficiency or increased risk of bleeding.

Monovalent DTI: Argatroban is l-arginine-based molecule, shorter activity and reversibly binds to thrombin. It has a half-life of 50 min and mainly excreted through the liver and requires dose adjustment in patients with hepatic impairment. It is given by intravenous route and monitored with aPTT levels [45]. Ximelagatran is a prodrug, given by the oral route and metabolized in the liver to active form, whereas melagatran has a predictable anticoagulation effect and longer half-life. Its clearance is not affected by liver impairment or moderate renal insufficiency and hence there is no need to monitor the levels unless the renal impairment is severe [46]. The major concern with DTI is the risk of bleeding and it is higher with lepirudin and desirudin when compared with argatroban and no specific antidote is available for DTI. PCC (Prothrombin complex concentrate) is increasingly used in reversing the DTI anticoagulation effect.

Danaparoid is a heparinoid derivative, interacts with anti-thrombin III to inhibit factor Xa. It is not available in USA, but used in few other countries. It has cross-reactivity with antibodies in 15% of the patients [47]. It's given subcutaneously or intravenously. Disadvantages are, it needs anti Xa level monitoring, has a long half-life (around 25 h), has renal excretion and absence of a reversal agent.

Fondaparinux is a synthetic pentasaccharide, it selectively inhibits factor Xa. The therapeutic dose of fondaparinux ranges from 5 to 10 mg/day, subcutaneously, although the levels can be measured, not required routinely. The disadvantages includes long half-life of around 17 hours, renal elimination and the lack of an antidote [48].

(DOACs) Direct oral anticoagulants are the oral anticoagulants that directly act on thrombin that is dabigatran or factor Xa inhibition, these are apixaban, edoxaban, rivaroxaban, they are not stimulating HIT antibodies. There is more experience was with rivaroxaban use in HIT patients. DOAC can be given as initial therapy or can be preceded by a parenteral agent in these patients.

SPECIAL SCENARIOS WHERE HEPARIN IS NEEDED BUT CANNOT BE USED DUE TO HIT

If patients on hemodialysis, percutaneous coronary Intervention (PCI), cardiopulmonary Bypass (CPB), unstable angina, thromboembolism, indwelling devices, valve replacement or intra-aortic balloon pump, develop HIT, they will require alternative anticoagulation therapy.

Hemodialysis

HIT antibodies are positive in up to 17% of the patients on hemodialysis with a significantly higher mortality. The manifestation of HIT in these patients varies from acute

systemic reaction to frequent clotting in the extracorporeal circuit or increase in the number of failed arteriovenous fistula. When HIT is suspected in these patients: all forms of heparin should be stopped and start DTI or danaparoid or regional citrate anticoagulation. Argatroban has advantage in these patients as no dose adjustment is required; the recommended dose is an initial bolus of 250 mcg/kg at the start of dialysis then continuous infusion of 2 mcg/kg/min until 1 h before the end of dialysis session. Only bolus dose of lepirudin recommended at the beginning of dialysis session. This DTI has to be monitored with aPTT [49].

Percutaneous coronary interventions and cardiopulmonary bypass

Hypercoagulability in HIT patients in combination with endovascular disruptions in PCI and CPB increases the risk of thrombosis. Argatroban, bivalirudin and danaparoid are the frequently used in PCI. If it is possible CPB surgeries should be postponed till PF4-heparin antibodies are negative, if cannot be delayed the bivalirudin, lepirudin, argatroban or danaparoid can be used.

Unstable coronary syndrome

These patients may need full anticoagulation for longer period, initially the intravenous argatroban is used successfully in HIT patients with unstable coronary syndrome and later on they can be managed with DOACs [50].

Multiple organ failure and HIT

Critically ill HIT patients with multiple organ dysfunction/failure and may have hepatic/renal impairment or failures, the dose of DTI must be adjusted with monitoring of the coagulation parameters and organ functions. The lack of antidote will put critical patients at the risk of potential risk of bleeding. Bivalirudin demonstrated better safety as it is cleared predominantly by the enzymatic cleavage.

Pregnancy and HIT

Fortunately HIT is rare in pregnancy. When a HIT patient becomes pregnant may require thromboprophylaxis and/or treatment for thrombosis. It is of extreme important to use an anticoagulant that causes the minimal risk to the developing fetus. Danaparoid, subcutaneous lepirudin and Fondaparinux are commonly used; there is limited literature available about their effects on fetus and newborn [51].

MORBIDITY AND MORTALITY

Early diagnosis and earlier management of HIT can reduce the morbidity and mortality, 20% of HIT patients with thrombosis need amputation [52]. In HIT patients treated with DTI, mortality decreases to 16% and the incidence of new thrombus decreases to 5.8% [53]. Small doses of thrombolytic agents were used locally in HIT patients with good results in massive pulmonary embolism or arterial thrombosis [54]. Ralph-Edward successfully managed a case of massive pulmonary embolism in a patient with HIT by embolectomy [55]. The immune memory in Hit patients lasts for 90 days in around 35% of patients. Immunoassay is positive up to 1 year [56]. Platelets come to the normal range in a week of discontinuation in approximately 65% of patients [57]. After the platelet count recovery, patients will be at risk for thrombosis for 4 to 6 weeks because of circulating anti-PF4/heparin antibodies. Patients who are re-exposed to the heparin months to years after antibody disappearance do not manifest anamnestic responses. In a small study of 17 patients with HIT who are re-exposed to heparin for cardiac surgery, a higher proportion of patients developed anti-PF4/heparin antibodies (65%) relative to the incidence described in the literature (~27% to 51%) [58].

PREVENTION

By following measures below will decrease the HIT occurrence (a) Keeping heparin therapy for shorter duration and starting warfarin early if expecting prolonged anticoagulation. (b) Avoiding bovine and fractional heparin and using LMWH. (3) Stopping the use of heparin flush for central and arterial catheters. (d) Heparin-free dialysis and not using heparin lock [59]. Sunnybrook Health Sciences Center, Toronto/Canada, implemented the “Avoid Heparin” campaign: in this campaign they replaced the use of UFH with LMWH for thromboprophylaxis and/or treatment, removed UFH from catheter flushes and nursing units. By this campaign the investigators found a significant reduction in percentage of occurrence of HIT [60,61].

CONCLUSION

For more than 100 years from the time of discovery, heparin remained most frequently used anticoagulant in the clinical practice. Its use is increasing as the patient population is getting older and number of vascular surgeries is increasing day by day. Heparin has advantages of rapid, shorter duration of Action and easy reversibility. The heparin induced thrombocytopenia (HIT) is a known but potentially life threatening complication of heparin use, it’s more frequent in females, young and surgical patients. HIT is diagnosed by 4T’s score in combination with laboratory test. The functional laboratory test (platelets aggregation test) is more specific but less sensitive and not routinely done. Immunoassay is commonly done laboratory test, it is sensitive but not specific. Optical density will increase the specificity of Immunoassays. Thrombocytopenia and thrombosis are common complications but the hemorrhage is rare in HIT patients. The management of HIT is summarized by 6 “A” Avoid heparin, alternative anticoagulation, anti PF4 antibodies detection, avoid platelet transfusions, await platelet recovery and asses for thrombosis. HIT can be prevented by use of porcine heparin, low molecular weight heparin, shorter duration of intravenous therapeutic heparin, avoiding heparin flush for central venous and arterial catheters and heparin lock.

REFERENCES

1. Wardrop D, Keeling D (2008) The story of the discovery of heparin and warfarin. Br J Hematol 141: 757-763.
2. Stéphan F, Hollande J, Richard O, Cheffi A, Maier-Redelsperger M, et al. (1999) Thrombocytopenia in a surgical ICU. Chest 115: 1363-1370.
3. Warkentin TE, Chang BH, Greinacher A (1998) Heparin induced thrombocytopenia: Towards consensus. Thromb Hemost 79: 1-7.
4. Martel N, Lee J, Wells PS (2005) Risk for heparin-induced thrombocytopenia with unfractionated and low-molecular-weight heparin thromboprophylaxis: A meta-analysis. Blood 106: 2710-2715.
5. Girolami B, Prandoni P, Stefani PM, Tanduo C, Sabbion P, et al. (2003) The incidence of HIT in hospitalized medical patients treated with subcutaneous heparin. Blood 101: 2955-2999.
6. Arepally GM, Ortel TL (2010) Heparin-induced thrombocytopenia. Annu Rev Med 61: 77-90.
7. Warkentin TE, Makris M, Jay RM, Kelton JG (2008) A spontaneous prothrombotic disorder resembling heparin-induced thrombocytopenia. Am J Med 121: 632.
8. Warkentin TE, Sheppard JA, Horsewood P, Simpson PJ, Moore JC, et al. (2000) Impact of the patient population on the risk for heparin-induced thrombocytopenia. Blood 96: 1703-1708.
9. Martel N, Lee J, Wells PS (2005) Risk for heparin-induced thrombocytopenia with unfractionated and low-molecular-weight heparin thromboprophylaxis: A meta-analysis. Blood 106: 2710-2715.
10. Smythe MA, Koerber JM, Mattson JC (2007). The incidence of recognized heparin-induced thrombocytopenia in a large, tertiary care teaching hospital. Chest 131: 1644-1649.
11. Warkentin TE, Sheppard JA, Sigouin CS (2006) Gender imbalance and risk factor interactions in heparin-induced thrombocytopenia. Blood 108: 2937-2941.
12. Shaikh N (2011) Heparin-induced thrombocytopenia. J Emerg Trauma Shock 4: 97-102.
13. Khandelwal S, Lee GM, Hester CG, Poncz M, McKenzie SE, et al. (2016) The antigenic complex in HIT binds to B-cells via complement and complement receptor 2 (CD21). Blood 128: 1789-1799.
14. Baroletti S, Hurwitz S, Conti NA, Fanikos J, Piazza G, et al. (2012) Thrombosis in suspected heparin-induced thrombocytopenia occurs more often with high antibody levels. Am J Med 125: 44-49.
15. Narins RC, Topo EJ (1997) Attention shifts to the white clot. Lancet 350: 2.
16. Warkentin TE (1998) Clinical presentation of heparin-induced thrombocytopenia. Semin Hematol 35: 9.
17. Warkentin TE, Kelton JG (2001) Temporal aspects of heparin-induced thrombocytopenia. N Engl J Med 344: 1286-1292.
18. Warkentin TE, Kelton JG (2001) Delayed-onset heparin-induced thrombocytopenia and thrombosis. Ann Intern Med 135: 502-506.
19. Hong AP, Cook DJ, Sigouin CS, Warkentin TE (2003) Central venous catheters and upper-extremity deep-vein thrombosis complicating immune heparin-induced thrombocytopenia. Blood 101: 3049.
20. Greinacher A, Farner B, Kroll H, Kohlmann T, Warkentin TE, et al. (2005) Clinical features of heparin-induced thrombocytopenia including risk factors for thrombosis. A retrospective analysis of 408 patients. Thromb Hemost 94: 132-135.
21. Warkentin TE, Elavathil LJ, Hayward CP, Johnston MA, Russett JI, et al. (1997) The pathogenesis of venous limb gangrene associated with heparin-induced thrombocytopenia. Ann Intern Med 127: 804-812.
22. Goel R, Ness PM, Takemoto CM, Krishnamurti L, King KE, et al. (2015) Platelet transfusions in platelet consumptive disorders are associated with arterial thrombosis and in-hospital mortality. Blood 125: 1470-1476.
23. Giossi A, Del Zotto E, Volonghi I, Costa P, Bertuetti R, et al. (2012) Thromboembolic complications of heparin-induced thrombocytopenia. Blood Coagul Fibrinolysis 23: 559-562.
24. Arthur CK, Grant SJ, Murray WK, Isbister JP, Stiel JN, et al. (1985) Heparin-associated acute adrenal insufficiency. Aust N Z J Med 15: 454-455.
25. Warkentin TE, Hirte HW, Anderson DR, Wilson WEC, O'Connell GJ, et al. (1994) Transient global amnesia associated with acute heparin-induced thrombocytopenia. Am J Med 97: 489-491.
26. Singla A, Amini MR, Alpert MA, Gornik HL (2013) Fatal anaphylactoid reaction associated with heparin-induced thrombocytopenia. Vasc Med 18: 136-138.
27. Shaikh N (2011) Heparin induced thrombocytopenia: Can be excluded. J Blood Disord Transfus S2: 001.
28. Lo GK, Juhl D, Warkentin TE, Sigouin CS, Eichler P, et al. (2006) Evaluation of pretest clinical score (4 T's) for the diagnosis of heparin-induced thrombocytopenia in two clinical settings. J Thromb Hemost 4: 759-765.
29. Linkins LA, Bates SM, Lee AY, Heddle NM, Wang G,

et al. (2015) Combination of 4Ts score and PF4/H-PaGIA for diagnosis and management of heparin-induced thrombocytopenia: Prospective cohort study. Blood 126: 597-603.

30. Cuker A, Arepally G, Crowther MA (2010) The HIT expert probability (HEP) score: A novel pre-test probability model for heparin-induced thrombocytopenia based on broad expert opinion. J Thromb Hemost 8: 2642-2650.
31. Lillo-Le Louët A, Boutouyrie P, Alhenc-Gelas M, Le Beller C (2004) Diagnostic score for heparin-induced thrombocytopenia after cardiopulmonary bypass. J Thromb Hemost 2: 1882.
32. Chong BH, Burgess J, Ismail F (1993) The clinical usefulness of the platelet aggregation test for the diagnosis of heparin-induced thrombocytopenia. Thromb Hemost 69: 344-350.
33. Nagler M, Bachmann LM, Ten Cate H, Ten Cate-Hoek A, et al. (2016). Diagnostic value of immunoassays for heparin-induced thrombocytopenia: A systematic review and meta-analysis. Blood 127: 546-557.
34. Levi M (2008) The coagulant response in sepsis. Clin Chest Med 29: 627-642.
35. Zidane M, Schram MT, Planken FW, Molendijk WH, Rosendaal FR, et al. (2000) Frequency of major hemorrhage in patients treated with unfractionated intravenous heparin for deep venous thrombosis or pulmonary embolism: A study in routine clinical practice. Arch Int Med 160: 2369-2373.
36. Pichford SC, Momi S, Banglioni S, Casali L, Gianni S, et al. (2008) Allergen induces the migration of platelets to the lung tissue in allergic asthma. Am J Respir Crit Care Med 177: 604-612.
37. Warkentin TE, Kelton JG (1996) A 14 year study of Heparin-induced thrombocytopenia. Am J Med 101: 502-507.
38. Warkentin TE, Levine MN, Hirsh J, Horsewood P, Roberts RS, et al. (1995) IT in patients treated with lower molecular weight heparin or fractional heparin. N Engl J Med 332: 1330-1335.
39. Bauer KA (2006) New anticoagulants: Anti-IIa vs. anti-Xa is better? J Thromb Thrombolysis 21: 67-72.
40. Kelton JG, Warkentin TE (1998) Heparin-induced thrombocytopenia. Diagnosis, natural history and treatment options. Postgrad Med 103: 169-171.
41. Warkentin TE (2004) Heparin induced thrombocytopenia: Diagnosis and management. Circulation 110: 454-458.
42. Srinivasan AF, Rice L, Bartholomew JR, La Perna L, Thompson JE, et al. (2004) Warfarin induced skin necrosis and venous gangrene in setting of heparin induced thrombocytopenia. Arch Intern Med 164: 66-70.
43. Linkins LA, Dans AL, Moores LK, Bona R, Davidson BL, et al. (2012) Treatment and prevention of heparin-induced thrombocytopenia: Antithrombotic therapy and prevention of thrombosis. 9th Edn. American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest 141: e495S-e530S.
44. Watson H, Davidson S, Keeling D (2012) Guidelines on the diagnosis and management of heparin-induced thrombocytopenia. 2nd Edn. Br J Hematol 159: 528-540.
45. Kam PC, Kaur N, Thong CL (2005) Direct thrombin inhibitors pharmacology and clinical relevance. Anesthesia 60: 565-574.
46. Greinacher A, Eichler P, Lubenow N, Kwasny H, Luz M (2000) HIT with thromboembolic complications; Meta-analysis of 2 prospective trails to assess the value of parental treatment with lepirudin and its therapeutic aPTT rang. Blood 96: 846-851.
47. Bartholomew JR (2005) Transition of oral anticoagulant in patients with HIT. Chest 127: 27S-34S.
48. Botson T, Perry CM (2002) Danaparoid: A review of its use in thromboembolic and coagulation disorders. Drugs 62: 2283-2314.
49. Goldfarb MJ, Blostein MD (2011) Fondaparinux in acute heparin-induced thrombocytopenia: A case series. J Thromb Hemost 9: 2501-2503.
50. Akamoto H, Shimada Y, Kanno T, Wanaka K, Matsuo T, et al. (2005) Role of platelet factor 4-heparin complex antibodies in pathogenesis of thromboembolic episodes in patients on hemodialysis. Hemodial Int 9: S2-7.
51. Lewis BE, Walenga JM (2002) Argatroban in HIT type II and acute coronary syndrome. Pathophysiol Hemost Thromb 32: 46-55.
52. Gerhardt A, Zotz RB, Stockschlaeder M, Scharf RE (2007) Fondaparinux is an effective alternative anticoagulant in pregnant women with high risk of venous thromboembolism and intolerance to low-molecular-weight heparins and heparinoids. Thromb Hemost 97: 496.
53. Jang IK, Hursping MJ (2005) When heparin promotes thrombosis: Review of heparin induced thrombocytopenia. Circulation 111: 2671-2683.
54. Parvin Kumar E, Webster NR (2003) HIT/HITT and alternative anticoagulation: Current concept. BJA 90: 676-685.

55. Calligaro KD, Kansagra A, Dougherty MJ, Savarese RP, DeLaurentis D, et al. (1995) Thrombolysis to treat arterial thrombotic complication of heparin induced thrombocytopenia. Ann Vasc Surg 9: 397-400.

56. Ralph-Edwards AC, Feindel CM, Glynn MF (1994). Successful treatment of massive pulmonary embolism after coronary bypass due to heparin induced thrombocytopenia. Ann Thorac Surg 57: 1326-1328.

57. Mattioli AV, Bonetti L, Zennaro M, Ambrosio G, Mattioli G (2009) Heparin/PF4 antibodies formation after heparin treatment: Temporal aspects and long-term follow-up. Am Heart J 157: 589-595.

58. Wallis DE, Workman DL, Lewis BE, Steen L, Pifarre R, et al. (1999) Failure of early heparin cessation as treatment for heparin-induced thrombocytopenia. Am J Med 106: 629-635.

59. Warkentin TE, Sheppard JAI (2014) Serological investigation of patients with a previous history of heparin-induced thrombocytopenia who is re-exposed to heparin. Blood 123: 2485-2493.

60. McGill RL, Blas A, Bialkin S, Sandroni SE, Marcus RJ, et al. (2005) Clinical consequences of heparin free dialysis. Hemodial Int 9: 393-398.

61. McGowan KE, Makari J, Diamantouros A (2016) Reducing the hospital burden of heparin-induced thrombocytopenia: Impact of an avoid-heparin program. Blood 127: 1954-1959.