Essential Thrombocythemia and Cardiac Surgery: A Case Series and Review of the Literature

Running Head: Essential Thrombocythemia and CV Surgery

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Abstract

Background: Essential thrombocythemia (ET) is a rare myeloproliferative disorder characterized by an unexplained thrombocytosis (>450 x10⁹/L) and associated vasomotor, thrombotic and hemorrhagic manifestations. While the literature detailing the perioperative management of patients with ET undergoing cardiac surgery is sparse, major perioperative complications have been reported, particularly in poorly controlled patients presenting with platelet counts ≥800 x 10⁹/L. The purpose of this study was to provide the experience at a large tertiary medical center in managing patients with ET undergoing cardiac surgery, and to summarize the available literature.

Methods: Patients with ET undergoing cardiac surgery between January 1, 2006 and May 1, 2016 were identified. Perioperative data were exhaustively reviewed and recorded. An extensive literature search for ET and cardiac surgery was performed.

Results: Twenty-five patients with ET underwent cardiac surgery during the study period. Twenty-four of 25 patients had immediate preoperative platelet counts < 800 x 10⁹/L. Perioperative complications related to ET occurred in 1 of 25 patients (4%), immediate preoperative platelet count 181 x 10⁹/L. A literature search identified 18 individual patients who underwent cardiac surgery with major perioperative complications occurring in 5 of 18 (28%), of which 4 of 5 had an immediate preoperative platelet count ≥ 800 x 10⁹/L.

Conclusions: Patients with ET undergoing cardiac surgery represent a complex cohort at risk for perioperative thrombotic and/or hemorrhagic complications. While not currently an indication for platelet reduction therapy by risk stratification criteria,¹ preoperative cyto reduction to platelet counts < 800 x 10⁹/L and perhaps lower should be considered in patients undergoing cardiac surgery.
Essential thrombocythemia (ET) is a rare myeloproliferative disorder characterized by pathologic expansion of the megakaryocytic elements in the bone marrow, leading to persistent thrombocytosis (>450 x 10^9/L) and platelet dysfunction. This disorder is commonly associated with somatically acquired mutations in the JAK2, CALR or MPL genes. Patients are often asymptomatic; however can develop vasomotor, hemorrhagic and/or thrombotic events with cerebral, myocardial and peripheral arterial thrombosis being the most frequent reported complications. The perioperative period risks both thrombosis and hemorrhage in patients undergoing cardiac surgery, particularly those with uncontrolled or untreated thrombocytosis. Prior studies described major perioperative complications in ET patients with platelet counts ≥800 x 10^9/L undergoing cardiac surgery. The literature detailing the perioperative management of patients with ET undergoing cardiac surgery is sparse. The purpose of this study was to provide the experience at a large tertiary medical center of patients with ET undergoing cardiac surgery, and to summarize the available literature related to this population.

Patients and Methods

Study setting, design and patient population

After approval from the Institutional Review Board at the Mayo Clinic in Rochester, Minnesota, a comprehensive computerized search of the electronic health records was conducted. Eligible patients included those with a diagnosis of essential thrombocythemia (ET) seen at Mayo Clinic, Rochester between January 1, 2006 to May 1, 2016 who underwent cardiac surgery. The diagnosis of ET conformed to the recent World Health Organization revised criteria for myeloid neoplasms.

Measurements

Medical records reviewed included outpatient and inpatient records, anesthetic records, laboratory data including transfusions received. Data collected included demographic information, surgery type,
perioperative laboratory values, platelet cytoreduction strategies, cardiopulmonary bypass (CPB) time, and allogeneic blood product requirements. Data collected on postoperative complications included: hemorrhagic and thrombotic events, acute renal failure necessitating hemodialysis, deep vein thrombosis (DVT, defined as postoperative ultrasound diagnosing acute DVT), pulmonary embolism (defined as computerized tomography or autopsy demonstrating acute pulmonary embolism), myocardial infarction (defined as new native coronary artery or coronary artery bypass graft occlusion demonstrated on postoperative cardiac catheterization), stroke or transient ischemic attack (defined as new postoperative stroke or transient ischemic attack being documented by a neurologist or on autopsy), and 90-day all-cause mortality.

Statistical analysis

The data were abstracted and entered into a spreadsheet (Excel; Microsoft Corporation, Redmond, WA, USA) from which simple calculations (mean, standard deviation, range) were determined.

Literature review

To enrich and inform the findings here, we searched PubMed using medical subject headings essential thrombocythemia and cardiac surgery. All articles written in the English language and any pertinent references were reviewed.
Results

Patients and operations

Over the study period, a total of 25 patients undergoing 25 cardiac procedures met our study criteria (female n=13). Demographic and clinical characteristics are shown in Table 1. Twenty-four of 25 operations utilized CBP (patient #15 underwent off-pump coronary artery bypass grafting, OPCAB). Of the 24 operations utilizing CBP, 2 patients (# 9, #19) underwent circulatory arrest. One patient required prolonged extracorporeal membrane oxygenator (ECMO) support in the setting of decompensated heart failure prior to undergoing total artificial heart implantation (patient #25).

The most frequent procedures performed were aortic valve replacement 6/25 (24%), coronary artery bypass grafting (CABG) 4/25 (16%) and combined aortic valve replacement and CABG 4/25 (16%). Valve replacement occurred in 13 patients (9 tissue, 4 mechanical). Two of 4 patients receiving mechanical valves (patient #2, #6) were on lifelong warfarin therapy prior to valve replacement. Twenty-four of the 25 patients (96%) were treated with cytoreductive agents (hydroxyurea, anagrelide or busulfan) or antiplatelet agents (aspirin or clopidogrel) prior to presentation for cardiac surgery. Fourteen (56%) of these patients were treated with cytoreductive and anti-platelet agents, 7 (28%) with cytoreductive agents alone, and 3 (12%) with anti-platelet agents alone. There were 5 (25%) patients anticoagulated with warfarin preoperatively, 3 patients with chronic atrial fibrillation and 2 patients with acute preoperative thromboembolism.

Preoperative patient characteristics

The majority of patients (64%) presented with an immediate preoperative platelet count < 450 x 10^9/L, with the overall cohort mean preoperative platelet count of 420 x 10^9/L (standard deviation +/- 280 x 10^9/L, range 61-1631 x 10^9/L). The mean preoperative hemoglobin concentration was 11.0 g/dL (+/- 2.0 g/dL, range 8.1-16.7 g/dL). One patient (patient #1) presented for CABG with a platelet count of 1631 x 10^9/L, and underwent intraoperative platelet reduction to reduce the platelet count to 758 x 10^9/L prior to
initiation of CPB, followed by an intravenous cangrelor infusion to further reduce thrombotic risk, and was previously detailed in the case report by Smith et al. ⁷

**Perioperative transfusions**

Eighteen (72%) patients received intraoperative transfusion, with the majority (67%) consisting of red blood cell transfusion (RBC) alone. Patients requiring intraoperative RBC transfusions had a lower preoperative hemoglobin concentration than patients not receiving RBC transfusion; mean 10.2 g/dL (+/- 1.46 g/dL) vs. 12.7 g/dL (+/- 1.92 g/dL). Of the 5 patients receiving platelet transfusions (patient #13, 18, 21, 23, 25), only one (patient #25) had an immediate preoperative platelet count < 100 X 10⁹/L. All 5 patients received platelet transfusions intraoperatively, and 1 patient (#25) also received transfusion in the ICU. The nadir pre-transfusion platelet counts in these patients were 609, 198, 132, 108, and 60 X 10⁹/L respectively. Transfusion of non-RBC components (i.e. fresh frozen plasma, platelets, cryoprecipitate) followed our cardiac surgical intraoperative transfusion algorithm throughout the study period. ⁸ While no algorithm exists for RBC transfusion at our institution, common clinical practice is to aim for a hemoglobin value > 8.0 g/dL, and avoidance of unnecessary transfusion.

The majority (80%) of the patients received intra-operative anti-fibrinolytic therapy consisting of either aminocaproic acid or tranexamic acid.

**Perioperative complications**

There were no intraoperative complications. Postoperative complications were noted in 4 patients (16%), of which 1 (4%) was felt to be likely related to ET (patient #21), and 1 (4%) possibly related to ET (patient #8). Patient #21 developed an acute lower extremity DVT on POD 5. Patient #8 developed postoperative transient loss of vision suggestive of a TIA which resolved within 24 hours. Patient #3 died after discharge on POD 20 secondary to complications related to heart failure. Patient #25 had advanced heart failure requiring ECMO support prior to undergoing total artificial heart implantation, and suffered several complications prior to transition to comfort cares on POD 46.
Duration of hospitalization and outcomes

Of the 24 patients surviving to hospital discharge, 18 (75%) were discharged on cytoreductive agents (hydroxyurea, anagrelide or busulfan), and 19 (79%) on antiplatelet agents (aspirin or clopidogrel). The mean POD 5 or day of discharge (if prior to POD 5) platelet count was 371 x 10^9/L (+/- 214 x 10^9/L, range 50-761 x 10^9/L); n=23. Twelve (50%) patients were discharged on warfarin; indications included 5 for valve repair/replacement, 5 with postoperative atrial fibrillation, and 2 with residual thromboembolic disease.

Literature review

The literature search revealed 18 published cases in the English language describing the perioperative course of patients with ET undergoing cardiac surgery (Table 2). Of 18 patients, 15 underwent cardiac surgery utilizing CPB and 3 had OPCAB. Major intraoperative or postoperative complications occurred in 5/18 (28%) patients, of which 4/5 had immediate preoperative platelet counts \( \geq 800 \times 10^9/L \). Preoperative cytoreductive strategies were not utilized in 3 of the 5 patients experiencing major thrombotic complications. There were 3 additional case reports published in languages other than English that were not included in this review.

Comment

Essential thrombocythemia is rare yet clinically relevant condition for which physicians caring for such patients undergoing cardiac surgery must be familiar. Previous case reports raise concern for major perioperative thrombotic complications in patients with poorly controlled ET undergoing cardiac surgery, with 80% of complications occurring in patients having platelet counts \( \geq 800 \times 10^9/L \) at time of surgery. We present here the largest case series of patients with ET undergoing cardiac surgery. Perioperative thrombotic complications related to ET occurred in 1 of 25 (4%) of cases, compared with 5 of 18 (28%) patients reported in the literature. In our study 24 of 25 patients had preoperative platelet
counts < 800 x 10⁹/L, with the remaining 1 patient undergoing intraoperative platelet reduction prior to CPB.

Essential thrombocythemia is a BCR-ABL1-negative myeloproliferative neoplasm characterized by pathologic expansion of the megakaryocytic elements in the bone marrow, leading to persistent thrombocytosis.²³ The incidence of ET is 9.6 new cases per 1,000,000 people, with higher incidence rates in African Americans and females.²³ This disorder is commonly associated with a somatically acquired mutation in the JAK2, CALR or MPL genes.²³ Treatment goals for patients with ET aim at preventing thrombotic, hemorrhagic, and vasomotor sequelae.²⁴-²⁶ Initiation of cytoreductive and/or anti-platelet therapy is largely determined by risk stratification which takes into account age, cardiovascular risk factors, history of thrombosis, and presence of JAK2 mutation.²⁴²⁵ When indicated, chronic therapies include cytoreduction with hydroxyurea, anagrelide, or alpha interferon, with plateletpheresis reserved for acute clinical situations (e.g. urgent surgery in a patient with extreme thrombocytosis). No consensus guidelines exist regarding the optimal platelet count to limit the risk of hemorrhagic or thrombotic complications but experts advocate maintaining platelet counts < 400 x 10⁹/L or lower depending on continued presence of symptoms.¹²⁷ Additionally, patients with ET and platelet counts of > 1000 x 10⁹/L may also have Acquired von Willebrand disease, which if present indicates need for initiation of cytoreductive therapy.²⁸

Cardiac surgery with the use of CPB is a complex physiologic event that leads to alterations in the hemostatic system through multiple mechanisms.²⁹ One such alteration is platelet activation and aggregation upon exposure to the CPB components.²⁹,³⁰ How these hemostatic derangements are altered in patients with ET is not completely understood, raising concern that in patients with uncontrolled ET, thrombosis within the bypass circuit or elsewhere in the circulation may occur during or soon after surgery resulting in potentially catastrophic complications.

The available literature consists of 18 published cases describing the perioperative course of patients with ET undergoing cardiac surgery requiring CPB (15) and also OPCAB (3) (Table 2).⁷⁻¹⁹ Of these 18 patients, 5 patients had major perioperative thrombotic complications consisting of myocardial
infarction, stroke, coronary artery thrombosis, pulmonary embolism, and ventricular fibrillation/cardiac arrest. Of these 5 patients, 4 of 5 (80%) had preoperative platelet counts ≥ 800 x 10^9/L, and 3 of 5 (60%) patients were not treated with cytoreductive therapies in the preoperative period. Of the 3 patients undergoing OPCAB, 1 patient died 5 hours postoperative from refractory ventricular fibrillation presumably to myocardial ischemia and possible coronary thrombosis. Thus while OPCAB may avoid thrombotic or hemorrhagic complications associated with CPB, these risks still exist postoperative in this population.

In our study, 1 patient (4%) had a postoperative thrombotic complication felt to be related to the diagnosis of ET (patient #21 - postoperative DVT). Patient #21 underwent extensive hypercoagulability workup which ultimately was attributed to ET. A second patient (#8) had a TIA which was unlikely related to ET. Two other patients had postoperative complications/death not felt to be related to the diagnosis of ET (patient #3, #25). In our study, 24 of 25 patients had platelet counts reduced to levels < 800 x 10^9/L before cardiac surgery, and the remaining 1 patient had intraoperative platelet reduction to decrease the platelet count to 758 x 10^9/L prior to initiation of CPB as was previous described by Smith et al. Of the 25 patients, 24 were receiving anti-platelet therapy and/or cytoreduction therapy prior to cardiac surgery.

The mean preoperative hemoglobin concentration in this cohort was 11.0 g/dL (+/- 2.0 g/dL, range 8.1-16.7 g/dL), likely at least partially resultant to the effects of cytoreductive therapies. There was an appreciably high intraoperative transfusion rate, 18 of 25 (76%) patients, with 17 of 18 receiving at least 1 unit of red blood cells. This is likely explained by the relative anemia seen in this population as the pre-op hemoglobin in those receiving RBC transfusion was 10.2 g/dL (+/- 1.46) compared to 12.7 g/dL (+/- 1.92) in patient’s not receiving RBC transfusion. Five patients received intraoperative platelet transfusion (patient # 13, 18, 21, 23, 25) with nadir pre-transfusion platelet counts of 609, 198, 132, 108, and 60 X 10^9/L respectively, likely a reflection of qualitative platelet dysfunction in these patients.

As mentioned previously, patients with a diagnosis of ET are risk stratified to determine need for long term antiplatelet and or cytoreductive therapy. Cytoreduction, when utilized is often to target platelet
counts in the normal range (\(< 400-450 \times 10^9/L\)) or lower depending on symptoms.\(^1\) While not an
indication for cytoreduction currently, one could argue that regardless of long term risk stratification, all
patients planned to undergo cardiac surgery should have platelet counts reduced \(< 800 \times 10^9/L\), or lower if
symptoms persist, as there appears to be an appreciable risk for major complications above this level.
Aggressive cytoreduction to levels far \(< 400 \times 10^9/L\) in absence of continued ET symptoms is likely
unwarranted and may risk worsening anemia and risk for transfusion.

Despite adequate platelet reduction, ET patients are still at risk for thrombotic or hemorrhagic
complications in the postoperative period as evidenced by patient #21 in our study (immediate pre-op
platelet count 181 \(\times 10^9/L\)), and the case described by Yorukoglu et al (immediate pre-op platelet count
326 \(\times 10^9/L\)).\(^{31}\) While hemorrhage is certainly a feared complication with ET due to a qualitative platelet
defect, all complications in our series and in the literature in this population undergoing cardiac surgery
were thrombotic in nature. Additional thrombotic risk reduction may be achieved with use of
intraoperative and/or perioperative cangrelor therapy (P2Y\(_{12}\) platelet receptor inhibitor with rapid onset
and short half-life) in high risk patients as was described in a prior report by Smith et al.\(^7\) While no
standards exist with regard to cyto-reductive and antiplatelet therapy in the immediate postoperative
period, early re-initiation of such therapy is likely warranted as is evidenced by the rapid rise in platelet
counts postoperatively and risk of thrombotic complications. Additionally, there may be a role for further
platelet inhibition in the early postoperative period; however, evidence to support these decisions will be
difficult to establish given the rarity of the disease.

In the current study, no patients developed heparin induced thrombocytopenia type 2 (HIT-2),
however, this life threatening complication has been described in patients with ET. Patients with ET may
be at risk for HIT-2 given the increased levels of platelet factor 4 in this population. Suspecting HIT-2 in
patients with ET presents a challenge since a platelet count drop of 50% from baseline will often remain
within the normal reference range for healthy adults.\(^{32}\) Providers must exercise a heightened sense of
vigilance with use of probability scoring systems (4T’s) and HIT antibody testing when necessary to help
diagnosis HIT-2. Given the paucity of data available on HIT in patients with ET, evidence based
recommendations are not feasible. However, institution of otherwise standard therapy for patients with HIT-2 (i.e. non-heparin direct thrombin inhibitor anticoagulation with eventual transition to warfarin) seems logical.\textsuperscript{33}

While difficult to develop a standardized approach to this patient population presenting for cardiac surgery given the paucity of published data and rarity of the condition, it is important to establish a reasonable approach given what is known regarding ET and cardiac surgery. We have composed an algorithm (figure 1) which takes into account the experiences at our center, and those summarized within the literature. Care for patients with ET will need to be largely individualized based on disease history, response to therapy, other medical comorbidities, and the operation required and timing of such.

The limitations of this study include all those inherit to a retrospective analysis, including charting omissions and the potential for data misinterpretation. Given that many patients present to our tertiary referral center specifically for perioperative care and then receive follow-up care elsewhere, comprehensive follow-up data may be incomplete.

**Conclusion**

Essential thrombocythemia is a rare disorder with clinically significant implications related to cardiac surgery. The perioperative period risks both thrombotic and hemorrhagic complications, however, lack of controlled studies preclude development of firm guidelines on optimal pre-operative platelet count. The association between significant intraoperative or perioperative complications or death is likely correlated with un-controlled thrombocytosis, but the exact platelet count cut off is not known. In the absence of evidence based guidelines, it is reasonable for patients presenting for cardiac surgery to undergo cytoreduction targeting a platelet count $< 800 \times 10^9$/L and perhaps lower to reduce the risk of catastrophic thrombotic and/or hemorrhagic complications in the perioperative period. Ideally, for elective surgical procedures, outpatient initiation or dose adjustment of chronic cytoreductive therapy may be ideal, however, for urgent/emergent surgery, platelethapheresis (preferred) or intraoperative platelet
reduction strategies may be the only option. Overly aggressive cytoreduction, however, in absence of ongoing symptoms related to ET may increase risk for anemia and perioperative transfusion in this surgical cohort. Early postoperative re-initiation of cytoreductive and anti-platelet therapy in the postoperative period to limit thrombotic risk is probably warranted.
References


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Abbreviations: AVR=aortic valve replacement; d/c= discharge; CABG= coronary artery bypass graft; CP= cryoprecipitate; CPB= cardiopulmonary bypass; DVT= deep venous thrombosis; FFP = fresh frozen plasma; Hgb=hemoglobin; Intra-op= intraoperative; L=liters; mL=milliliters; MV=mitral valve; N= none; OPCAB=off-pump coronary artery bypass grafting; OR=operating room; PLT =platelet units; Pre-op= preoperative; post-op= postoperative; POD= postoperative day; PTE=pulmonary thrombo-endarterectomy; RBC= red blood cells; TAH=total artificial heart; ♂= male; ♀= female

^ Hemoglobin laboratory reference range 12-15.5 g/dL; Platelet laboratory reference range 150-450 x10⁹/L
*Patient underwent intraoperative platelet reduction via an autologous transfusion technique
†Preoperative Warfarin in the setting of atrial fibrillation
‡Preoperative Warfarin in the setting chronic DVT/PE
§ Pt on ECMO support leading up to operation
Table 2. Reported cases of cardiac operations in patients with essential thrombocythemia.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Age(yr), Gender, Operation</th>
<th>Pre-op Therapy</th>
<th>Nearest Platelet Count Prior to OR (x10^9/L)</th>
<th>Post-op Therapy</th>
<th>Complications/Mortality</th>
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<tbody>
<tr>
<td>Pick et al. 1983&lt;sup&gt;15&lt;/sup&gt;</td>
<td>26 ♂, CABG</td>
<td>N</td>
<td>1500</td>
<td>Plateletpheresis</td>
<td>N</td>
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<td>Scheffer et al. 1991&lt;sup&gt;16&lt;/sup&gt;</td>
<td>47 ♂, CABG</td>
<td>Busulfan</td>
<td>694</td>
<td>Aspirin</td>
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<td></td>
<td>59 ♀, CABG</td>
<td>Busulfan</td>
<td>750</td>
<td>Busulfan</td>
<td>N</td>
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<td>62 ♂, CABG</td>
<td>Aspirin</td>
<td>812</td>
<td>Aspirin</td>
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<tr>
<td></td>
<td>75 ♂, CABG</td>
<td>Busulfan</td>
<td>854</td>
<td>Busulfan</td>
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<tr>
<td>Yoshida et al. 1991&lt;sup&gt;19&lt;/sup&gt;</td>
<td>52 ♂, CABG</td>
<td>Melphalan</td>
<td>400</td>
<td>Melphalan</td>
<td>N</td>
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<tr>
<td>Momiyama et al. 1993&lt;sup&gt;13&lt;/sup&gt;</td>
<td>58 ♂, CABG</td>
<td>N</td>
<td>1412</td>
<td>Dipyridamole Melphalan Ticlopidine</td>
<td>Post-op myocardial infarction and stroke</td>
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<tr>
<td>Schott 1994&lt;sup&gt;18&lt;/sup&gt;</td>
<td>67 ♀, CABG</td>
<td>Plateletpheresis and plasma exchange</td>
<td>280</td>
<td>Aspirin</td>
<td>N</td>
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<tr>
<td>Haddad et al. 2003&lt;sup&gt;12&lt;/sup&gt;</td>
<td>26 ♂, CABG</td>
<td>N</td>
<td>800</td>
<td>Aspirin Dipyridamole Warfarin</td>
<td>Intra-op coronary thrombus requiring subsequent LVAD insertion, heart transplantation 3 months</td>
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<tr>
<td>Study</td>
<td>Follow-up</td>
<td>Intervention</td>
<td>Event Rate</td>
<td>Adverse Events</td>
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<tr>
<td>Daya et al. 2004&lt;sup&gt;11&lt;/sup&gt;</td>
<td>31 ♀, CABG</td>
<td>N</td>
<td>1178</td>
<td>Anagrelide Hydroxycarbamide PE</td>
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<td>Nurkalem et al. 2006&lt;sup&gt;14&lt;/sup&gt;</td>
<td>71 ♂, CABG</td>
<td>Hydroxyurea Plateletpheresis</td>
<td>400</td>
<td>Anagrelide N</td>
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<td>Yorukoglu et al. 2006&lt;sup&gt;31&lt;/sup&gt;</td>
<td>61 ♂, OPCAB</td>
<td>Anagrelide Heparin</td>
<td>326</td>
<td>-- VF arrest and death 5 hours post-op</td>
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<td>Ahmed et al. 2008&lt;sup&gt;9&lt;/sup&gt;</td>
<td>22 ♂, AVR</td>
<td>Interferon</td>
<td>301</td>
<td>Aspirin Heparin Warfarin N</td>
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<td>Kaya et al. 2009&lt;sup&gt;4&lt;/sup&gt;</td>
<td>65 ♂, OPCAB</td>
<td>Aspirin Hydroxyurea</td>
<td>680</td>
<td>Aspirin Clopidogrel Hydroxyurea N</td>
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<td>Scholzel et al. 2010&lt;sup&gt;17&lt;/sup&gt;</td>
<td>36 ♂, CABG</td>
<td>Aspirin Hydroxyurea LMWH</td>
<td>1438</td>
<td>Aspirin Intra-op coronary thrombus, post-op tamponade and PE</td>
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<td>Das et al. 2011&lt;sup&gt;10&lt;/sup&gt;</td>
<td>73 ♂, CABG</td>
<td>Hydroxyurea Plateletpheresis</td>
<td>367</td>
<td>Hydroxyurea N</td>
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<tr>
<td>Darwazah et al. 2014&lt;sup&gt;5&lt;/sup&gt;</td>
<td>71 ♂, OPCAB</td>
<td>Clopidogrel Hydroxyurea</td>
<td>600</td>
<td>Aspirin Clopidogrel Hydroxyurea</td>
<td>N</td>
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<td>---------------------------------</td>
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<tr>
<td>Smith et al. 2017&lt;sup&gt;7&lt;/sup&gt;</td>
<td>75 ♂, CABG</td>
<td>Busulfan</td>
<td>1631→758 *</td>
<td>Aspirin Hydroxyurea Warfarin</td>
<td>N</td>
</tr>
</tbody>
</table>

Abbreviations: d/c= discharge; CABG= coronary artery bypass grafting; Intra-op=intraoperative; L=Liters; LMWH=low molecular weight heparin; LVAD=left ventricular assist device; N=none; NR=not reported; OPCAB=off-pump coronary artery bypass grafting; Pre-op= preoperative; PE=pulmonary embolism; Post-op= postoperative; POD= postoperative day; VF=ventricular fibrillation; yr=years; ♂= male; ♀= female;

<sup>5</sup>Platelet laboratory reference range 150-450 x10<sup>9</sup>
<sup>6</sup>Patient underwent intraoperative platelet reduction via an autologous transfusion technique<sup>7</sup>
<sup>7</sup>Search limited to English language**
Figure Legend

Figure 1. Management of patients with essential thrombocythemia presenting for cardiac surgery.
Patient with diagnosis of Essential Thrombocytopenia (ET) requiring Cardiac Surgery

Platelet count $\geq 800 \times 10^9/L$ OR continued ET related symptoms

- Elective Surgery
  - Delay surgery 2-4 weeks
  - Consult Hematology if not already involved for initiation or dose adjustment of oral cytoreductive therapy; goal platelet count $\geq 800 \times 10^9/L$ AND resolution of any ET related symptoms
  - Consider perioperative anti-platelet therapy in high thrombotic risk patients

- Urgent or Emergent Surgery
  - Plateletpheresis (preferred)
  - Intraoperative platelet reduction if urgency precludes preoperative plateletpheresis
  - Consider perioperative anti-platelet therapy in high thrombotic risk patients

- Proceed to Surgery
  - Consider perioperative anti-platelet therapy in high thrombotic risk patients
  - Early postoperative reconstitution of cytoreductive and antiplatelet therapy

Platelet count $< 800 \times 10^9/L$ AND lack of ET related symptoms

- Proceed to Surgery
  - Early postoperative reconstitution of cytoreductive and antiplatelet therapy