Role of Echocardiography in Patients Undergoing Elective Cardioversion of Atrial Fibrillation

David I. Silverman, MD; Warren J. Manning, MD

Abstract—Echocardiography has emerged as a fundamental tool in the evaluation of patients with atrial fibrillation (AF). Transthoracic echocardiography remains a primary tool for the evaluation and management of many patients presenting with their first episode of AF, but it is not adequate for exclusion of atrial thrombi. TEE offers excellent visualization of the atria and accurate identification or exclusion of thrombi. In concert with therapeutic anticoagulation, a TEE-guided approach to early cardioversion appears to have a safety profile similar to that of conventional therapy (1 month of precardioversion warfarin). The TEE-guided approach offers the advantages of simplified anticoagulation management and shorter duration of sustained AF, thereby allowing for a more rapid recovery of atrial mechanical function. Warfarin should be continued for 1 month after cardioversion to allow for more complete recovery of atrial function and for prophylaxis should the patient revert to AF. Cost-effectiveness models demonstrate that TEE-guided cardioversion represents a cost-effective strategy, but only if the transthoracic echocardiogram is omitted. For patients with a thrombus on the initial TEE, follow-up TEE (to document thrombus resolution) is recommended before cardioversion. (Circulation. 1998;98:479-486.)

Key Words: fibrillation ■ echocardiography ■ cardioversion ■ anticoagulants ■ atrial flutter

Atrial fibrillation (AF) is the most common sustained arrhythmia and is responsible for almost 300 000 hospital admissions annually. Its prevalence increases from <1% among those <60 years old to almost 9% among octogenarians. Characterized by lack of organized atrial electrical and mechanical activity, AF is typically associated with a rapid ventricular response that results in alterations in the patient’s clinical and hemodynamic state. The loss of atrial systolic contribution to total ventricular filling leads to depressed cardiac output and symptoms of dyspnea and fatigue. In addition, the resulting stasis of blood, enhanced platelet aggregation, and coagulation predisposes to the formation of atrial thrombosis and subsequent thromboembolism, the most feared complication of AF.

Role of Transthoracic (Surface) Echocardiography

For patients presenting with their first episode of AF, transthoracic (surface) echocardiography is often advocated for initial evaluation and management. Many cardiac disorders associated with AF, including mitral valve disease, hypertensive heart disease (left ventricular hypertrophy), ischemic heart disease (left ventricular systolic dysfunction), pericarditis, and cor pulmonale (right ventricular enlargement/dysfunction) are readily diagnosed by transthoracic echocardiography. In addition, information regarding left ventricular systolic function is often used to guide the choice of ventricular rate–controlling agent, because some agents used for this purpose (eg, verapamil, β-blockers) are less appropriate in the setting of left ventricular systolic dysfunction. The absence of structural heart disease detected by transthoracic echocardiography can also be used to identify AF patients for whom chronic therapy with aspirin (versus warfarin) may be preferred. Because of its frequent inability to adequately image the left atrial appendage, however, transthoracic echocardiography is neither sensitive nor specific for the identification or exclusion of atrial thrombi, the site of the majority of thrombi among patients with AF.

Although transthoracic echocardiography is not an adequate imaging modality for identifying or excluding atrial thrombi, it is an excellent technique for assessment of left atrial size. Two-dimensionally guided M-mode echocardiography allows for the measurement of left atrial dimension in the parasternal long-axis orientation. M-mode–derived left atrial size has been shown to correlate well with angiographically derived left atrial areas and volumes and has been used to monitor changes in left atrial size in AF. Left atrial enlargement is common among patients with AF. Several echocardiographic studies have shown that sustained (chronic) AF is associated with progressive left and right atrial enlargement and that cardioversion and maintenance of sinus rhythm will reverse this process. Conflicting data have been reported on the relationship between mild or moderate left atrial enlargement and prognostic importance.
Regarding long-term maintenance of sinus rhythm. Because of the uncertainty of mild to moderate left atrial enlargement as a predictor of successful cardioversion and long-term maintenance of sinus rhythm, we believe that left atrial enlargement alone should not be used as a criterion to decide for or against an attempt at cardioversion. In practice, we generally attempt cardioversion for almost all patients who present with their first episode of AF, assuming that the duration of AF is brief and reversible causes of AF have been treated (eg, hyperthyroidism). Patients with chronic (>1 year) AF, rheumatic mitral valve disease, and left atrial dimension >6.0 cm, however, are less likely to have long-term maintenance of sinus rhythm. Finally, patients presenting with recurrent or chronic AF probably do not benefit from serial echocardiographic studies unless there is a change in their clinical status (eg, new heart failure).

Role of 3 to 4 Weeks of Prophylactic Warfarin Before Cardioversion

Although cardioversion of AF to sinus rhythm is advocated in an effort to improve cardiac function, relieve symptoms, and decrease the risk of thrombus formation, successful cardioversion may be associated with clinical thromboembolism. Patients with sustained AF for ≥2 days are subjected to a 5% to 7% risk of cardioversion-related clinical thromboembolism if cardioversion is not preceded by several weeks of warfarin (Table 1).

Although cardioversion in the absence of prolonged warfarin administration is associated with clinical thromboembolism in a substantial minority of patients, both prospective and retrospective studies have reported that the use of 2 to 4 weeks of warfarin before cardioversion results in a reduction in the thromboembolic rate to approximately 1.2%. This 80% improvement in thromboembolic complications has led to the widespread acceptance of this 1 month of prophylactic warfarin use before cardioversion.

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Although warfarin prophylaxis offers the benefit of a reduction in cardioversion-related thromboembolism, this comes at the cost of a delayed cardioversion for the vast majority of patients without thrombi who could otherwise undergo early and safe cardioversion. The delay in cardioversion exposes the patient to prolonged warfarin therapy (with associated risk of hemorrhagic complications) and also to prolonged duration of AF before cardioversion.

Among patients who receive warfarin in preparation for cardioversion, major hemorrhagic complications (defined as complications requiring hospitalization, blood transfusion, or urgent surgery) are reported in 1% to 2% of patients before cardioversion. For these patients, warfarin is often fully reversed to minimize further morbidity, yet the patient remains in AF. Minor complications (epistaxis, hematuria, menorrhagia) have been reported in an additional 6% to 18% of patients. For patients with these minor complications, the clinician is faced with the difficult choice of reducing the intensity of anticoagulation, often to a subtherapeutic range (with the patient still in AF) or continuing warfarin at the risk of continued or progressive bleeding.

Although several weeks of treatment with warfarin is recommended before elective cardioversion, patients often do not receive a full course of prophylactic warfarin before cardioversion because of concern for hemorrhagic complications. Recent data demonstrate that at least 25% of patients without contraindications to warfarin may not receive 1 month of prophylactic warfarin before cardioversion. The proportion of elderly patients who do not receive 1 month of prophylactic warfarin may exceed 50%. Even among patients for whom prophylactic warfarin is intended, transient subtherapeutic prothrombin times are common. For these patients, a strategy of increasing the warfarin dose and restarting the “1-month clock” is generally prescribed.

Benefits and Risks of TEE Approach to Cardioversion

A diagnostic imaging technique that provides accurate identification or exclusion of atrial thrombi would allow for early and safe cardioversion for those patients in whom thrombi are not present. Such an approach would allow for an abbreviated total duration of anticoagulation (by shortening the duration of precardioversion warfarin) and also minimize the total duration of AF before cardioversion.

In most patients, anatomic imaging and assessment of the body of the left atrium may be readily obtained from transthoracic (surface) echocardiography, but exclusion of left atrial thrombi by this method is quite limited because of its relative inability to adequately visualize the left atrial appendage, the site of the majority (90%) of atrial thrombi among patients with AF. By contrast, transesophageal echocardiography (TEE), a moderately invasive but well-tolerated procedure, provides high-resolution imaging of the body of the atrium and the left atrial appendage. Comparative intraoperative series have demonstrated the excellent sensitivity and predictive accuracy of TEE for the identifica-
tion and exclusion of left atrial thrombi \cite{36-40} (Table 3, Figure 1). Achieving this level of diagnostic accuracy, however, demands a systematic and careful examination of the atria and appendages for thrombi.\cite{30,41} Biplane and multiplane imaging appear to be superior to monoplane imaging.\cite{39-41}

Validation data on TEE accuracy for right atrial appendage thrombi (Figure 2) are currently unreported, but presumably there is similar accuracy. Isolated right atrial appendage thrombus (in the absence of left atrial thrombus) also appears to be quite rare.\cite{28,32,33,41}

In addition to reduced risk of anticoagulation, several physiological arguments can be made for shortening the duration of AF before cardioversion. Long-term maintenance of sinus rhythm is inversely related to the duration of AF before cardioversion.\cite{42,43} In addition, the recovery of atrial mechanical function has been shown to be inversely related to the duration of AF before cardioversion.\cite{44} Thus, patients with AF <2 weeks before cardioversion demonstrate near-complete return of atrial mechanical function within 24 hours of cardioversion, whereas patients with AF of 2 to 6 weeks require up to a week and those with AF for >6 weeks require up to 3 weeks for full recovery of atrial mechanical function.\cite{44}

At our hospitals, almost 60% of patients hospitalized for treatment of AF have been in AF for ≥1 month.\cite{32,41} The conventional use of 1 month of prophylactic anticoagulation before cardioversion serves to more than double the total period of AF before cardioversion. This delay prolongs recovery of atrial function and potentially reduces the likelihood of long-term maintenance of sinus rhythm.\cite{42,43}

### TEE-Guided Cardioversion With Heparin/Warfarin Anticoagulation

We\cite{32,41} and others\cite{28,33} have advocated the use of TEE to guide early cardioversion in concert with therapeutic heparin (or warfarin) beginning at the time of TEE and extending to 1 month after cardioversion (Figure 3). The rationale for the use of anticoagulation in this manner is based on two assumptions: (1) that the spatial resolution for TEE is adequate to detect clinically relevant thrombi and (2) that heparin/warfarin anticoagulation will prevent the formation of new, clinically relevant thrombi during the interval between TEE and cardioversion and during the postcardioversion period. Conversion to sinus rhythm, whether spontaneous,\cite{45} pharmacological,\cite{46,47} or electrical,\cite{33,46,48} has been shown to be associated with relatively depressed left atrial and left atrial appendage mechanical function\cite{33} and therefore with increased risk for thrombus formation.\cite{44} The use of systemic anticoagulation for 1 month after cardioversion serves to inhibit the formation of new thrombi during the subsequent recovery of atrial function.

At least 4 independent, prospective trials\cite{28,32,33,41,49} have now examined the safety of a TEE-guided approach to early cardioversion among patients presenting with AF of ≥48 hours’ duration (Table 4). These studies demonstrate that ∼15% of patients presenting with AF will have atrial thrombi identified by TEE. Predictors of atrial thrombi have included atrial spontaneous echocardiographic contrast,\cite{32,33,41} depressed left ventricular systolic function,\cite{38,32,41} and initial presentation with clinical thromboembolism.\cite{41} In contrast to

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**Table 3. Sensitivity, Specificity, and Accuracy of Transesophageal Echocardiography for Left Atrial Thrombi**

<table>
<thead>
<tr>
<th>Study</th>
<th>Probe</th>
<th>No. of Patients</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Accuracy, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mügge\cite{36}</td>
<td>Mono</td>
<td>12</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Olson\cite{37}</td>
<td>Mono</td>
<td>20</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Hwang\cite{38}</td>
<td>Mono/Bi</td>
<td>213</td>
<td>93</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>Manning\cite{39}</td>
<td>Mono/Bi/Mult</td>
<td>231</td>
<td>100</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Fatkin\cite{40}</td>
<td>Bi</td>
<td>60</td>
<td>100</td>
<td>93</td>
<td>93</td>
</tr>
</tbody>
</table>

Mono indicates monoplane; Bi, biplane; and Mult, multiplane.
With the anticoagulation strategy described, early cardioversion in patients without TEE evidence of thrombi has resulted in no clinical thromboembolic complications among almost 300 prospectively studied patients (combined 95% CI, 0% to 1%). Safety data from a pilot prospective study directly comparing conventional treatment of AF (4 weeks of warfarin before cardioversion) with the TEE-guided approach also appear favorable for the TEE strategy with regard to safety and anticoagulation management/comlications but not for maintenance of sinus rhythm. Data from the much larger, multicenter ACUTE (Assessment of Cardioversion Using Transesophageal Echocardiography) Study are not expected for several years and will include >3000 patients. This study will also include a large outpatient population. Until the final ACUTE data are known, the TEE-guided approach to cardioversion should be considered as having a safety profile similar to, but not safer than, conventional therapy. Patients ideally suited for the TEE-guided approach include those patients at an increased risk for warfarin morbidity and those with a relatively short (<1 month) duration of AF at presentation.

Patients with TEE evidence of atrial thrombi or those in whom the left atrial appendage cannot be adequately visualized (thrombus cannot be excluded) should not undergo early cardioversion but rather should be treated with 4 weeks of warfarin. As might be anticipated, the presence of an atrial thrombus by TEE confers an adverse prognosis. In our experience, despite maintenance of systemic anticoagulation and sustained AF, 10% of these patients die during their index admission. Of survivors with nonvalvular AF, the vast majority (>80%) of thrombi resolve during the subsequent month of warfarin anticoagulation. Others have reported lower morbidity/mortality rates and also lower rates of thrombus resolution. These apparent discrepancies in morbidity/mortality rates and rates of thrombus resolution are probably related to differences in the patient populations studied.

**TEE-Guided Cardioversion Without Heparin/Warfarin Anticoagulation**

Although reports on the use of TEE-guided early cardioversion in concert with heparin/warfarin commencing at the time of TEE and extending to 1 month after cardioversion are quite promising, adverse events have been well described among

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**TABLE 4. Incidence of Thrombi and Safety of Early Cardioversion Among Patients Referred for Transesophageal Echocardiography–Guided Cardioversion**

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Patients</th>
<th>No. (%) of Patients With Left Atrial Thrombi</th>
<th>No. (%) of Patients With Successful Cardioversion</th>
<th>No. (%) of Postcardioversion Thromboembolisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manning(^{12,41})</td>
<td>233†</td>
<td>34 (15)</td>
<td>186 (95)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Stoddard(^{33})</td>
<td>206‡</td>
<td>37 (18)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Klein(^{28})</td>
<td>62§</td>
<td>7 (13)</td>
<td>38 (84)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Corrado(^{49})</td>
<td>118</td>
<td>12 (10)</td>
<td>106 (100)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

*Of patients without atrial thrombi.
†3 (1.3%) patients could not complete transesophageal echocardiography.
‡46 patients received short-term anticoagulation.
§6 patients did not undergo transesophageal echocardiography.
patients with a “negative” TEE who have undergone early cardioversion without systemic anticoagulation. Thromboembolisms in these reports have uniformly occurred in patients who have not received therapeutic anticoagulation before TEE and extending 3 to 4 weeks after cardioversion. Many underwent electrical cardioversion several days or weeks after TEE with no anticoagulation during this interval. For these patients, it is impossible to exclude the possibility that atrial thrombi formed either between the TEE and cardioversion or after cardioversion. Impaired atrial mechanical function, new left atrial spontaneous echo contrast, and even thrombus formation have all been documented after successful cardioversion.

As in our original report, we strongly recommend that all patients being considered for TEE-guided early cardioversion be anticoagulated with intravenous heparin/warfarin followed by TEE only when a therapeutic partial thromboplastin time has been achieved. Reports of clinical thromboembolism among patients not treated in this manner underscore the importance of this anticoagulation strategy. Early cardioversion should be performed if the atria and appendages are adequately seen and thrombi can be excluded. Systemic anticoagulation should then be continued for 3 to 4 weeks after cardioversion to prevent thrombi from forming in the postcardioversion period. If a thrombus is seen on TEE or if severe spontaneous echo-cardiographic contrast or appendage trabeculations preclude thrombus exclusion, then cardioversion should be deferred and the patient maintained on warfarin for 4 weeks. We then advocate a follow-up TEE to document thrombus resolution before attempted cardioversion. After 4 weeks of warfarin, TEE resolution is seen in 50% to 85% of patients. Although there are no randomized data to support the use of the second TEE, thromboembolism after 4 weeks of warfarin (among patients treated with conventional therapy) are most likely related to residual thrombi. Preliminary cost-effectiveness data also support this second TEE approach. To the best of our knowledge, no data are known on the likelihood of residual thrombus after an additional 4 or 8 weeks of warfarin. We generally do not perform serial TEE until thrombus has completely resolved but rather treat these patients with chronic warfarin and avoid cardioversion.

Cost Effectiveness of a TEE-Guided Approach to Early Cardioversion

In today’s healthcare environment, the cost of a novel treatment strategy must be considered in addition to its therapeutic benefit. If two strategies are similar in effectiveness, then the less costly approach should be advocated. The cost/benefit analysis of a TEE-guided approach to cardioversion must include an accounting of (1) the morbidity from TEE, (2) the additional financial cost of performing the TEE itself, and (3) costs for caring for patients who suffer thromboembolism after a negative TEE. The cost-effectiveness of the TEE-guided approach has been examined by use of decision analytic models. With hospital costs (not charges) used, the TEE-guided approach has been identified as being more cost-effective for hospitalized patients with AF, but only when the initial transthoracic (surface) echocardiogram is eliminated. This result is because transthoracic echocardiography cannot adequately exclude atrial thrombi. We therefore advocate omission of the transthoracic echocardiogram for patients for whom a TEE-guided approach is planned, and we have implemented this expedited TEE strategy at our hospitals (Figure 3). In addition, it is important to proceed with expeditious TEE after hospitalization. Any cost savings are attenuated (or even reversed) if TEE is delayed and hospital stay is prolonged.

As in our original report, we strongly recommend that all patients being considered for TEE-guided early cardioversion be anticoagulated with intravenous heparin/warfarin followed by TEE only when a therapeutic partial thromboplastin time has been achieved. Reports of clinical thromboembolism among patients not treated in this manner underscore the importance of this anticoagulation strategy. Early cardioversion should be performed if the atria and appendages are adequately seen and thrombi can be excluded. Systemic anticoagulation should then be continued for 3 to 4 weeks after cardioversion to prevent thrombi from forming in the postcardioversion period. If a thrombus is seen on TEE or if severe spontaneous echo-cardiographic contrast or appendage trabeculations preclude thrombus exclusion, then cardioversion should be deferred and the patient maintained on warfarin for 4 weeks. We then advocate a follow-up TEE to document thrombus resolution before attempted cardioversion. After 4 weeks of warfarin, TEE resolution is seen in 50% to 85% of patients. Although there are no randomized data to support the use of the second TEE, thromboembolism after 4 weeks of warfarin (among patients treated with conventional therapy) are most likely related to residual thrombi. Preliminary cost-effectiveness data also support this second TEE approach. To the best of our knowledge, no data are known on the likelihood of residual thrombus after an additional 4 or 8 weeks of warfarin. We generally do not perform serial TEE until thrombus has completely resolved but rather treat these patients with chronic warfarin and avoid cardioversion.

Role of TEE-Guided Cardioversion for Patients With AF of <48 Hours

The general belief (and clinical implication) that the incidence of atrial thrombi among patients with relatively brief (<2 days) duration of AF is very low has recently come under closer scrutiny. Using TEE, Stoddard and coworkers reported left atrial thrombi in 14% of patients with AF of <3 days’ duration, compared with a frequency of 27% among patients with AF of ≥3 days. These provocative data prompted us to examine the incidence of thromboembolism among patients presenting with AF of <48 hours’ duration. In a consecutive series of >350 hospitalized patients with nonvalvular AF of <48 hours’ duration, we found that >95% of these patients either spontaneously converted or were actively converted to sinus rhythm during the index admission. None had screening TEE. The incidence of cardioversion-related thromboembolism was 0.8%, and all events occurred in patients who had spontaneously converted to sinus rhythm. The incidence of thromboembolism was similar to the expected incidence of thromboembolism had this entire group been treated with warfarin for 1 month before cardioversion. Preliminary data from Mitchell and colleagues are also consistent with these patients’ being at very low risk of postcardioversion thromboembolism. Accordingly, we do not advocate screening TEE or prolonged warfarin before cardioversion for these patients, except for patients at very high risk for thromboembolism (history of prior/recent thromboembolism, rheumatic valvular disease, left ventricular systolic dysfunction). Although the benefit has not been proven, we do recommend that patients presenting with AF of <48 hours’ duration be anticoagulated with heparin at the time of presentation so as to minimize the likelihood that a thrombus will develop and so that they are “protected” during the periconversion period of atrial appendage dysfunction. As discussed earlier, if this is the patient’s first presentation with AF, transthoracic echocardiography is reasonable to evaluate possible mitral valve disease, left ventricular systolic dysfunction, etc.

Role of TEE for Patients With Atrial Flutter

Sustained atrial flutter is a far less common arrhythmia. As a result, fewer data are known regarding risk of cardioversion-
related thromboembolism and atrial function after cardioversion.

The relatively “preserved” atrial mechanical function seen with atrial flutter had been thought to convey a lower risk of thromboembolism (compared with AF). In the largest series of patients with atrial flutter undergoing cardioversion, no patient in either the anticoagulation or the nonanticoagulated group experienced a clinical thromboembolic event (Table 5).26,62,64

More recently, however, several cases of atrial thrombi identified during TEE study in patients with sustained atrial flutter have been reported. In one recent study of nonanticoagulated patients with sustained atrial flutter for 4 weeks, the incidence of atrial thrombi was 11%,65 a frequency comparable to that in patients with AF. Two recent preliminary studies from larger series have also shown an incidence of left atrial thrombi of 4% to 6%,66,67 with thrombi seen primarily among atrial flutter patients with mitral valve disease or severe left ventricular systolic dysfunction. These provocative data suggest a possible benefit of prolonged (1 month) warfarin or screening TEE before cardioversion for patients with atrial flutter for >48 hours, especially those at high clinical risk for thromboembolism (mitral valve disease, depressed left ventricular systolic function, or a history of thromboembolism).67 Because atrial thrombi and thromboembolism among patients with alternating AF and flutter have been well described,27 patients with this presentation should be treated conservatively with AF strategies.

### Summary

Echocardiography has emerged as a fundamental tool in the evaluation of patients with AF. Transthoracic echocardiography remains a primary tool for the evaluation and management of many patients presenting with their first episode of AF, but it is not adequate for exclusion of atrial thrombi. TEE offers excellent visualization of the atria and accurate identification or exclusion of thrombi. In concert with therapeutic anticoagulation, a TEE-guided approach to early cardioversion appears to have a safety profile similar to that of conventional therapy (1 month of precardioversion warfarin). The TEE-guided approach offers the advantages of simplified anticoagulation management and shorter duration of sustained AF, thereby allowing for a more rapid recovery of atrial mechanical function. Warfarin should be continued for 1 month after cardioversion to allow for more complete recovery of atrial function and for prophylaxis should the patient revert to AF. Cost-effectiveness models demonstrate that TEE-guided cardioversion represents a cost-effective strategy, but only if the transthoracic echocardiogram is omitted. For patients with a thrombus on the initial TEE, follow-up TEE (to document thrombus resolution) is recommended before cardioversion.

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### References


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