Experience in 2643 Patients

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Background: Patients who undergo neurosurgical procedures are at high risk for perioperative deep vein thrombosis (DVT) and pulmonary embolism (PE), which have been reported in 6% to 43% of these patients.

Objectives: To (1) determine the utility of prospective DVT surveillance in patients who undergo neurosurgical procedures by using venous duplex ultrasound scanning (VDUS), (2) assess the efficacy of DVT prophylaxis (elastic stockings and intermittent pneumatic compression), (3) identify subgroups of patients who are at higher risk, and (4) determine whether DVT surveillance would reduce the incidence of fatal PE.

Design: All patients had undergone preoperative VDUS of both lower extremities, and postoperative VDUS was performed on days 3 and 7, and weekly thereafter until patients were ambulatory or discharged.

Patients: During a 5-year period, 2643 patients who underwent neurosurgical procedures were enrolled in prospective DVT surveillance.

Setting: University-affiliated community hospital.

Results: Acute DVT was diagnosed in 147 (5.6%) of the 2643 patients. Eighty-one percent of the patients with acute DVT were asymptomatic at the time of diagnosis. Deep vein thrombosis developed de novo in the proximal veins in 98% of the patients. Patients in whom a craniotomy was done had a significantly higher risk for DVT (7.7%, P=.006), and patients who underwent cervical or lumbar spinal surgical procedures had a significantly lower risk (1.5%, P<.001).

Among those patients in whom a craniotomy was performed for treatment of a tumor and who had DVT, 87% had malignant neoplasms. Significant lower-extremity neuromotor dysfunction was present in 69% of all patients with DVT, and this finding predominated among patients with DVT in the subgroups with a lower risk. A PE was diagnosed in 3 patients (0.19%) while they were hospitalized, and a PE was fatal in 2 (0.07% of all patients).

Conclusions: Most perioperative DVTs were clinically silent and formed spontaneously in proximal venous segments where there would be a risk for a PE. The overall incidence of DVT (5.6%) was low, suggesting effective DVT prophylaxis. Patients who underwent spinal surgical procedures were at a significantly lower risk for DVT, and future surveillance is not indicated in this patient group unless other conditions exist (paralysis, malignancy). Patients in whom a craniotomy was performed had a significantly higher risk of DVT, particularly when other risk factors existed. The low incidence of a fatal PE (0.07%) reflected that early detection and treatment of proximal DVT were facilitated by prospective VDUS surveillance in these patients.

ESPITE DECADES of modern intensive study of techniques for prevention of deep vein thrombosis (DVT) and pulmonary embolism (PE), these entities remain a major cause of death and morbidity in hospitalized patients. Estimates suggest that at least 260,000 cases of clinically recognizable venous thromboembolism occur annually among hospitalized patients in the United States and that PE is the direct cause of death in more than 100,000 patients each year and contributes to the deaths of at least another 100,000 patients. In addition, PE has
PATIENTS AND METHODS

From 1987 through 1991, a total of 2643 patients who were admitted to the Chicago (Ill) Neurosurgical Center of Columbus Hospital were entered into a prospective surveillance program by using VDUS for the detection of acute and perioperative DVT. The study group comprised more than 98% of patients who were admitted to this service during this period, and all patients who were undergoing major neurosurgical procedures were included, with the exceptions noted below. The mean age of the patients in the study group was 58 years (age range, 18 to 92 years) and included 1372 men (51.9%) and 1271 (48.1%) women.

The following surgical and other procedures were performed in these patients. Craniotomies were performed in 1439 patients (54.4%) for treatment of neoplasms or cerebrovascular disorders (eg, intracranial aneurysms or arteriovenous malformations). Ventriculoperitoneal or other shunting procedures were performed in 299 patients (11.3%), and cervical or lumbar spinal surgical procedures were performed in 454 patients (17%); this latter figure represents approximately 80% of the patients who underwent spinal surgical procedures during this entire period. Following the initial review of this surveillance program in which no DTVs were detected in 100 patients who underwent spinal surgical procedures, the protocol was altered to include only those patients with other associated risk factors (age, >60 years, malignant neoplasms, neuromotor dysfunction, history of DTV, etc). There were 119 patients (4.5%) who had undergone a variety of other neurosurgical procedures (eg, stereotactic brain biopsy, cranioplasty, management of wounds, etc) and 332 patients (12.6%) who were enrolled in a surveillance program but had not undergone any surgical procedures. This latter group included patients who were hospitalized with symptomatic intracranial aneurysms and who received no surgical treatment, patients with symptomatic spinal stenosis, patients who were treated with a gamma knife, and patients who had undergone prior surgical procedures with associated clinical risk factors for DVT.

VENOUS THROMBOSIS PROPHYLAXIS

All patients in this study had bilateral knee-length elastic compression stockings applied. Intermittent mechanical compression was also performed in all patients by using a calf-length single-chamber device. Intermittent pneumatic calf compression was begun preoperatively and continued intraoperatively and postoperatively until the patient was fully ambulatory or until discharge in those patients with sustained lower-extremity neuromotor dysfunction. All patient care was conducted in dedicated neurosurgical intensive care areas and wards where personnel were specifically instructed about the program of prophylaxis and surveillance. Compliance was monitored under the direction of a dedicated clinical nurse specialist (M.T.).

VENOUS DUPLEX ULTRASOUND SCANNING

Venous duplex ultrasound scans were performed on both legs of all patients preoperatively and on postoperative days 3 and 7. Repeated VDUS was performed thereafter at weekly intervals until discharge in patients who remained immobilized or who had significant lower-extremity neuromotor dysfunction. Additional scans were performed at the request of the managing physicians if patients exhibited significant clinical changes. The protocol for VDUS surveillance generally remained consistent throughout the period of this report, with the exception of patients who had undergone lumbosacral or cervical spinal procedures and who had their VDUS surveillance protocol altered significantly following preliminary data analysis in November 1988. As noted above, only patients who had undergone spinal surgical procedures and who were at a higher risk were enrolled in surveillance, and scans were performed 1 week postoperatively or prior to discharge.

The technique for performance of VDUS has become standardized, and its details have been thoroughly described in other reports.29,30 Venous duplex ultrasound scanning in this study was performed from the confluence of the tibial veins to the common femoral vein at the inguinal ligament. Longitudinal and transverse B-mode images, combined with pulsed wave Doppler or color Doppler assessments, were obtained from the popliteal, superficial femoral, deep femoral, and common femoral veins. Scanning was carried centrally into the iliac veins and vena cava when it was clinically indicated, but it was not performed routinely. Scanning of the calf veins was not routinely performed as a part of this protocol. Patients were examined in the vascular laboratory when possible, but most examinations in this study were conducted at the bedside. Venous duplex ultrasound scanning was performed with a variety of commercially available ultrasound units—all from a single manufacturer (Advance Technology Laboratories, Bothel, Wash).

The VDUS diagnostic criteria for acute DVT have also become standardized,29,30 and these criteria were applied throughout the study. Prior to the initiation of this surveillance program, the diagnostic accuracy of VDUS for acute proximal DVT (94%) in our vascular laboratory had been determined by comparison with findings from contrast phlebograms.30 Most of the DTVs in this study were diagnosed by using direct visualization of discrete homogeneous echogenic intraluminal-filling defects. In other cases, an echolucent clot produced distended, incompressible venous segments. An accurate diagnosis was facilitated in many cases by comparison with prior normal preoperative or interval scans. Acute DTVs, diagnosed in this study, were classified by their anatomic location. Early on in this study, it was recognized that an isolated common femoral vein thrombosis was a characteristic finding in patients in the surveillance protocol, and these patients were empirically given a separate classification in this report. Thrombi in the common femoral vein that extended any distance above the inguinal ligament were classified as iliofemoral, and scanning was always performed to delineate their most proximal central extension. Close involvement of the popliteal or superficial femoral vein were classified together as femoropopliteal, and thrombi that were identified below the popliteal were termed calf vein thrombi.

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While technologic modifications in the ultrasound equipment that evolved during the period of this study (including the addition of color-flow duplex scanning) enhanced the performance of VDUS, it was not thought by either the physicians or the vascular technologists that the overall diagnostic accuracy for detection of DVT in these patients was significantly altered. Contrast phlebograms were performed in a small number of patients in this series when there were uncertainties about the VDUS or when clinical events did not correlate with scan results. Phlebographic findings are included in this report only when they are clinically relevant. The incidence of acute DVT in different clinical groups (see below) was compared by using the chi-square analysis, and comparisons of mean values were performed by using a paired t test. A P < .05 was chosen to indicate statistically significant differences.

been implicated in up to 3% of postoperative deaths related to neurosurgical procedures. Consensus studies and meta-analyses have mandated the routine use of DVT prophylaxis in patients who undergo neurosurgical procedures, and it was thought reasonable to consider a program of DVT surveillance in this high-risk, high-prevalence group.

Prospective surveillance studies to detect DVT in high-risk patient groups have used invasive and noninvasive diagnostic techniques as well as combinations of both. Contrast phlebography has been the diagnostic standard to which other techniques have been compared, but the complexity, risk, discomfort, and cost of phlebograms make this technique unrealistic for repetitive examinations. Decades ago, iodine 125-labeled fibrinogen uptake tests were used effectively for the diagnosis of DVT in prospective surveillance studies. However, these examinations were more accurate for the diagnosis of inconsequential calf vein thromboses than for clinically relevant proximal iliofemoral DVT, and this technique is no longer used since the pooled-plasma product is unavailable. Physiologic noninvasive tests (eg, impedance plethysmography) were very accurate for the diagnosis of proximal symptomatic DVT, and these tests could be easily repeated at intervals without risk to the patients. However, the diagnostic accuracy of impedance plethysmography was compromised when it was used in prospective screening of asymptomatic high-risk patients.

Venous duplex ultrasound scanning (VDUS) has become the most universally accepted noninvasive technique for the diagnosis of lower-extremity DVT. This technique allows accurate, direct imaging of venous anatomy and, like contrast phlebography, direct visualization of in situ venous thromboses. Unlike phlebography, VDUS can be repeated at intervals; thus, it is suitable for prospective surveillance studies. The diagnostic accuracy of VDUS for detection of acute DVT has been extensively studied, and most well-designed comparisons with contrast phlebograms have reported sensitivities and specificities in excess of 90% for duplex ultrasound scanning in symptomatic patients. Barnes et al also demonstrated that the diagnostic accuracy of VDUS was equivalent to that of contrast phlebography for proximal DVT (above the calf level) in a prospective study of asymptomatic high-risk patients who had undergone joint replacement procedures. In most hospital settings, this technique has supplanted phlebography for the initial diagnosis of DVT.

The present report details an extended experience with VDUS surveillance for the detection of acute and perioperative DVT in patients who underwent neurosurgical procedures. The goals of this report were to examine the efficacy of DVT prophylaxis in these patients and to identify subgroups of patients who were at a higher risk and thus allow the continued modification of such a surveillance program. Another goal was to compare these summary observations with findings in a preliminary report that contained far fewer patients with DVT to determine the validity of our original observations and conclusions.

RESULTS

ACUTE DVT

Acute DVT was diagnosed in 147 of the 2643 patients who underwent neurosurgical procedures and who were entered into the surveillance program for an overall incidence of 5.6%. The mean age of patients who had acute DVT was 60 years (age range, 21 to 87 years), which was not significantly different from the mean age of the all patient group. Acute DVT was observed in the right leg alone in 64 patients (43.5% of all DTVs), was confined to the left leg in 68 patients (46.2%), and was bilateral in 15 patients (10.2%). Femoropopliteal DTVs were observed in 99 patients (67.3%) (Figure 1), isolated common femoral vein thrombi were diagnosed in 40 patients (27.2%), iliofemoral DTVs were seen in 5 patients, and calf vein thrombosis was detected in 3 patients.

Deep vein thrombosis was diagnosed in asymptomatic patients as the result of the scheduled surveillance scan in 120 (81.6%) of 147 patients. All DTVs in these asymptomatic patients were proximal DTVs (femoropopliteal veins, 85 patients; common femoral veins, 35 patients). The remaining 27 cases of acute DVT were diagnosed by VDUS that was requested outside the usual surveillance intervals based on patients’ symptoms or their changing clinical conditions. Preoperative DTVs were diagnosed in 27 patients (18.4% of DTVs), and the remaining 120 cases of DTV were diagnosed postoperatively. Twenty-three of the 27 patients with preoperative DTVs and the remaining 120 cases of DTV were diagnosed postoperatively. Twenty-three of the 27 patients with preoperative DTVs had been transferred from another inpatient facility; 25 patients with preoperative DTVs (92.6%) were asymptomatic at the time of their initial surveillance scan. Figure 2 is a graphic representation of the occurrence of symptomatic and asymptomatic DTVs at different time intervals during the surveillance program.

A craniotomy had been performed in 111 of the 147 patients who had acute DVT. A craniotomy had been performed for treatment of a tumor in 86 patients (58.5% of DTVs) (Figure 3), and for neurovascular disorders
in 25 patients (17% of DVTs). Acute DVT occurred in 18 patients who underwent shunting procedures (12.2%) and in only 7 patients who underwent cervical or lumbar spinal procedures (4.8%). The remaining 11 cases of DVT (7.5%) occurred in patients who received other surgical or nonsurgical treatments.

Table 1 summarizes the occurrence of the major known risk factors, malignant neoplasms, and lower-extremity neuromotor dysfunction in patients who had acute DVT in this study. Among the 86 patients who underwent a craniotomy for treatment of a tumor in whom acute DVT developed, 75 (87%) were found to have malignant neoplasms. In the entire group of 147 patients who had acute DVT, 93 patients were found or known to have malignant neoplasms (63.3% of all DVTs). Understandably, patients in whom DVT developed following a craniotomy for neurovascular disorders, spinal surgery, and shunt procedures did not have a high incidence of malignant neoplasms (20%, 28.6%, and 16.7%, respectively). However, 8 (72.7%) of 11 patients who had DVT following "other" surgical or nonsurgical treatments were known or found to have malignant neoplasms.

Lower-extremity neuromotor dysfunction was present in 101 (68.7%) of the 147 patients in whom acute DVT developed. Table 1 lists the frequency of neuromotor dysfunction among patients who had acute DVT in the different clinical groups. The presence of this independent risk factor was remarkably similar throughout the various groups, but it was particularly notable among the otherwise low-risk subgroups. More than 85% of patients who had DVT after they underwent spinal surgical procedures had neuromotor dysfunction. This was not significantly higher than any other clinical group (P=.32) since the case numbers were too small to draw reliable statistical conclusions. Nevertheless, it seems to be an undeniable clinical observation that these patients were at the highest risk of an otherwise very low-risk patient subgroup.

Table 2 lists the incidence of DVT in all patients who were enrolled in the DVT surveillance program in each of the arbitrarily defined clinical treatment groups. Here, as previously detailed in paragraph 2 of the "Patients and Methods" section, patients who underwent a craniotomy for treatment of a tumor or neurovascular disorders are combined. Also, patients who underwent other surgical procedures and those who had nonsurgical treatments were combined in this analysis. Acute DVT occurred in 7.7% of all patients who underwent a craniotomy. The incidence of DVT was significantly higher in the group of patients in whom a craniotomy was performed than in the entire patient group (P=.007). The incidence of DVT was strikingly higher in the group of patients in whom a craniotomy was performed than in the group of patients who underwent spinal surgical procedures (1.5%, P<.001) or patients who received other treatments (2.4%, P<.001). Patients who underwent spinal surgical procedures had the lowest incidence of DVT (1.5%), and this was statistically significantly lower than that in the entire patient population (P<.001).

Contrast phlebography was performed in 10 patients with abnormal findings from VDUS, and it confirmed the acute DVT in 8 patients. Chronic postthrombotic changes, noted on VDUS, were confirmed by results of phlebography in 1 patient. One scan in the early part of the experience demonstrated a nonocclusive thrombus in the common femoral vein. Phlebography in this
Table 1. Incidence of Malignant Neoplasms and Significant Lower-Extremity Neurotomy Dysfunction in Patients Who Underwent Neurosurgical Procedures and Who Had Acute DVT Diagnosed During the Surveillance Period

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Malignant Neoplasms, No. (%)</th>
<th>Neurotomy Dysfunction, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craniotomy</td>
<td>86(75)</td>
<td>60(65)</td>
</tr>
<tr>
<td>Neurovascular disorder</td>
<td>25(50)</td>
<td>20(60)</td>
</tr>
<tr>
<td>Verticalintraspinal shunt</td>
<td>18(16.7)</td>
<td>12(67)</td>
</tr>
<tr>
<td>Cervical or lumbar spinal</td>
<td>7(24.6)</td>
<td>6(35.7)</td>
</tr>
<tr>
<td>Other</td>
<td>11(72.7)</td>
<td>7(63.6)</td>
</tr>
<tr>
<td>All Patients, Total</td>
<td>147(93.3)</td>
<td>101(65.7)</td>
</tr>
</tbody>
</table>

*DVT indicates deep vein thrombosis; VOUS, venous duplex ultrasound scanning.

Table 2. Incidence of Acute DVT Diagnosed by Using VDUS in Each of the Clinical Treatment Groups

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Total No. of Patients</th>
<th>DVT, No. (%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craniotomy</td>
<td>1490</td>
<td>111(7.71)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Shunt</td>
<td>299</td>
<td>18(6.02)</td>
<td></td>
</tr>
<tr>
<td>Cervical or lumbar spinal</td>
<td>454</td>
<td>7(1.54)</td>
<td>&lt;0.001‡</td>
</tr>
<tr>
<td>Other</td>
<td>451</td>
<td>11(2.43)</td>
<td>&lt;0.001‡</td>
</tr>
<tr>
<td>All Patients, Total</td>
<td>2845</td>
<td>147(5.56)</td>
<td></td>
</tr>
</tbody>
</table>

*DVT indicates deep vein thrombosis; VDUS, venous duplex ultrasound scanning.
†Significantly higher than that for total patient group.
‡Significantly lower than that for total patient group.

in our original report. The present report reviews 7 to 8 times more patients and the same additional numbers of patients with acute DVT, and would seem to strengthen the validity of many of our previous conclusions. However, it also serves to emphasize some of the fundamental issues of DVT surveillance in very high-risk patient groups.

1. Was the system of DVT prophylaxis successful? The overall incidence of DVT in the entire group of patients was 5.6%—similar to the 4.7% incidence in our initial report. This extended experience would certainly appear to support the efficacy of the DVT prophylaxis (a combination of elastic stockings and pneumatic calf compression) that was used to treat these patients. While valid statistical comparisons are not possible, it is probably reasonable to conclude that the observed incidence of 5.6% is significantly lower than the 24% incidence of DVT in untreated control subjects in previous reports of DVT prophylaxis in patients who underwent elective neurosurgical procedures and in historic reports of a 29% to 43% incidence of DVT in patients who underwent neurosurgical procedures when no DVT prophylaxis was used. While the incidence of 5.6% is similar to the 6% reported by Cerrato et al, it appears lower than the 7% to 9% in other reports of patients who underwent neurosurgical procedures in which DVT prophylaxis was used. These differences (if real) are undoubtedly the result of the fact that no attempt was made to diagnose isolated calf vein thrombi in the present surveillance study. Calf vein thrombi have accounted for the majority of perioperative DVTs in other reports of patients who underwent neurosurgical procedures when phlebography was used for the diagnosis. In a recent report that used phlebography for diagnosis, Geerts et al observed that 69% of DVTs in trauma patients were calf vein thrombi, and these thrombi were discovered 2 to 3 times more frequently than proximal DVTs in every clinical subgroup of patients examined. Thus, it is possible that if calf vein thromboses were diagnosed in the present study, the overall incidence of DVTs would have been 10% to 15%—a range of values that was very similar to those cited above.

2. Most proximal vein DVTs do not propagate out of the calf but form de novo in the major axial venous segments. Acute DVTs were observed from the popliteal vein to the common femoral vein in 95% of the pa-
patients in the present report. This compares with the 88% incidence of DVTs in the major axial venous segments of the limb in our original review. The anatomic classification has been changed somewhat in the present report to call attention to the frequently observed occurrence of focal spontaneous common femoral vein DVT in patients in the surveillance protocol (this was seen in 27.2% of all DVTs in this series). In a prospective VDUS surveillance program in trauma patients, Napolitano et al. observed acute DVT in the common femoral veins in 82.2% of patients. These observations would suggest that clinically relevant DVTs will be detected by using surveillance, since it is well accepted that most fatal PEs arise from the proximal veins.44,45 The reality of this latter observation was underscored by 1 patient in this series who suffered a fatal PE following VDUS diagnosis of acute DVT before therapy could be started and by another patient for whom treatment was withheld based on a normal phlebogram.

As noted above, the scanning protocol for these patients did not include routine examination of calf veins, and it is certain that cases of isolated calf vein thrombosis were not diagnosed. Routine calf vein scanning increases the technologic complexity of the examination and roughly doubles the time that is required for testing an individual patient; this would significantly increase the indirect costs of these examinations (see below). Several studies have reported the remarkable diagnostic accuracy of VDUS for examination of calf veins, but most investigators regard calf vein scanning as a continued source of diagnostic error.46-48 When extensive DVT is present in the calf veins, it will usually be evident during routine VDUS that does not specifically examine the calf or will produce symptoms that will be suggestive enough to warrant direct examination as it did in 3 patients in the present study. When DVTs remain confined to the calf, they are far less likely to cause a clinically significant PE.49-51 However, 2 patients in the present series had a PE that was diagnosed by using a pulmonary arteriogram despite normal serial VDUS. These cases (0.07% of patients) could certainly be considered to represent a PE originating from undiagnosed calf vein thromboses, but the PE in these cases might also have originated from pelvic veins (as demonstrated by phlebography in 1 patient) or from undiagnosed upper-extremity DVT. Overall, no patient with normal findings from VDUS surveillance suffered a fatal PE while he or she was hospitalized. The decision not to perform calf vein scanning as a part of the routine surveillance protocol did not appear to compromise either therapeutic decisions or patient safety in this study.

3. Most DVTs in high-risk patients are asymptomatic. For decades, it has been recognized that symptoms or physical findings are unreliable clinical indicators of acute DVT. However, the magnitude of the problem of asymptomatic proximal DVT in high-risk groups is probably underestimated by most practitioners. Napolitano et al.11 diagnosed asymptomatic major proximal DVTs by using VDUS surveillance in 10% of trauma patients who were treated with standard DVT prophylaxis. Burns et al. reported clinically occult DVTs in 21% of trauma patients who were studied with serial venous ultrasound scanning. Acute DVT was diagnosed by using phlebography in 58% of trauma patients who did not receive DVT prophylaxis in the study by Geerts et al.,20 and 98.5% of these patients had no clinical characteristics of DVT. In the present study, 81.6% of patients with DVT were asymptomatic at the time of diagnosis by using the surveillance VDUS, and all had proximal DVTs. It has been well recognized that the first manifestation of thromboembolic disease may be a fatal PE, and reliance on diagnosis and treatment of established, symptomatic DVT exposes patients to an unacceptable period of risk for embolization of proximal DVTs. Our data would suggest that early diagnosis and treatment of major proximal DVTs reduces the risk of a PE in hospitalized patients who undergo neurological procedures (0.19% of all patients in this study); this figure is almost identical.
to the 0.2% incidence of PEs in trauma patients who were described by Napolitano et al.43 (in these patients, VDUS surveillance facilitated early diagnosis and treatment of asymptomatic proximal DVTs).

There are some aspects of the VDUS surveillance protocol that were unique to the population of patients who underwent neurosurgical procedures in this study; however, these aspects are generally relevant to an overall consideration of surveillance of high-risk groups. Acute DVT was diagnosed with the use of the preoperative or admission VDUS in 27 (18.4%) of the 147 patients with DVT. This observation was clearly the result of many patients being transferred from other in-patient facilities after a period of hospitalization or a prior surgical procedure. This is a particularly important observation for this group since without these preliminary examinations, many patients might have been taken to surgery with, in situ DVT and a measurable period of risk for PE prior to the first postoperative surveillance scan. However, these observations would be irrelevant to surveillance of other high-risk groups (eg, trauma patients) that would be unlikely to harbor occult DVT prior to admission. The majority of acute DVT (68.7%) were diagnosed within 14 days postoperatively, and this period accounted for 73% of the asymptomatic DVTs. Napolitano et al.43 observed that 93% of all DVTs that were discovered by VDUS surveillance were diagnosed by the first 2 scans. After the first 2 weeks, the mean occurrence of DVT in the present study was 30 days, and 34.7% of those patients were symptomatic at the time of diagnosis. These findings would suggest that surveillance programs may be modified to serve effectively different patient populations at risk and to cover specifically periods of higher risk.

Venous duplex ultrasound scanning for DVT surveillance in high-risk groups has not been universally successful. Pooled results from 6 studies that screened high-risk patients showed an overall sensitivity of 59% for VDUS although the specificity was 98%.42.43 Davidson et al.44 reported a sensitivity of only 38% for color Doppler ultrasonography in the detection of proximal leg vein thrombi in patients who underwent hip or knee replacement procedures. This latter study is possibly the low watermark for prospective DVT surveillance is not indicated in these patients where proximal DVT was detected in only 6% of the patients who they studied; these authors speculated that if VDUS was reserved for only symptomatic high-risk patients, this would represent a 72% savings in the cost of examinations, and they noted parenthetically that the true incidence of fatal PE in patients with undiagnosed, untreated proximal DVT is really unknown. More recent prospective studies of trauma patients have diagnosed proximal DVT in 10% to 18% of patients who were asymptomatic in 98% to 100% of the cases. If the sort of therapeutic nihilism suggested by Meyer et al.46 is broadly applied in the name of cost-containment, then we, as physicians, have become part of the problem—not part of the solution. While it is unequivocally true that the patient who dies promptly costs less to care for, we do not believe that this particular philosophy of cost-containment should drive diagnostic and therapeutic strategies in the new millennium. The results of our current review suggest that significant modifications can be made in this and any other surveillance program to increase its effectiveness and reduce costs. Patients who underwent spinal surgical procedures had a significantly lower risk of DVT, especially those patients who underwent operations on the cervical spine. We conclude that prospective DVT surveillance is not indicated in these patients, with the possible exception of those patients with significant lower-extremity neuromotor dysfunction or malignant neoplasms. The same recommendation can also be made for patients who undergo neurosurgical procedures and miscellaneous procedures or nonsurgical treatments. These modifications alone would reduce the current patient population by one third. Patients in whom
a craniotomy was performed, especially those for malignancy, had a significantly higher risk for perioperative DVT in this study. We would continue to recommend VDUS surveillance of these high-risk patients. A PE occurred in only 0.18% of hospitalized patients in this series, and the only fatal PE in this group occurred in patients in whom VDUS had accurately diagnosed DVT. While 1 of these deaths was arguably preventable, it is likely that a fatal PE rate of 0.07% among hospitalized, high-risk patients represents an improvement over historic observations. One homily with regard to the interpretation of statistical significance has been that "to be different, it has to make a difference." We believe that prospective surveillance for perioperative DVT in patients who underwent neurosurgical procedures in this study made a difference in the occurrence of a fatal PE in these patients.

CONCLUSIONS

Prospective surveillance in 2643 patients who underwent neurosurgical procedures by using lower-extremity VDUS diagnosed acute DVT in 5.6% of the patients. Proximal vein DVTs were diagnosed in 98% of the patients, and 82% of the patients with DVT were asymptomatic at the time of diagnosis. Patients who underwent a craniotomy, especially for malignant neoplasms or with lower-extremity neuromotor dysfunction, had a significantly higher risk of DVT. Patients who underwent spinal surgical procedures had a significantly lower risk of DVT, and future surveillance is probably not justified in patients who undergo uncomplicated operations on the cervical or lumbar spine. A PE was diagnosed in 5 hospitalized patients (0.19% of cases) and was fatal in 2 patients (0.07%).

No diagnostic or therapeutic strategy will eliminate a fatal PE. However, interval surveillance with the use of VDUS provides an accurate, noninvasive, and cost-effective means for diagnosis of DVT; during well-defined periods of risk, it will significantly increase the detection of clinically silent proximal DVT in well-defined, high-risk patient groups and allow for effective treatment. Thus, this type of surveillance will reduce the incidence of a fatal PE in such patients.

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REFERENCES

Yeins were not routinely examined in the study, do the results reflect the incidence of DVT in craniotomy patients at 7-7% vs cervical and lumbar spinal patients at 1.5%, is only a 7.7% incidence of DVT high enough to justify the added cost of a screening program in this era of cost-containment vs using some other type of prophylaxis?

Robert Wilson, MD, Detroit, Mich: What sort of preoperative coagulation studies do the authors perform? If they find abnormalities, what changes do they make in their management? We also know that neurosurgery or brain trauma can cause intravascular coagulation and a tendency to disseminated intravascular coagulation. I wonder how much of that particular abnormality they saw in these patients.

Dr Flinn: The issue of calf vein thrombosis remains a controversial one. If we look at prospective studies with venographic control, with the study from Toronto in trauma patients being the best and most recent one, the majority of DVTs detected are calf vein DVTs, and so it stands to reason that in our program, there were a substantial number of isolated calf vein DTVs that were not detected. It was the philosophy of our protocol, early on, that isolated calf vein DTVs were clinically irrelevant to the outcome of fatal PE, and that is how we proceeded. It seems, based on our long-term results, that this was a justifiable assumption, but it remains an area of concern. However, this issue is also relevant to the area of cost. When routine calf vein scanning is performed on every patient, it roughly doubles the time of the examination and, of course, ultimately contributes to increased indirect costs.

Comparing prophylaxis with surveillance, current studies would indicate, even with good prophylaxis in high-risk groups, that we will see an incidence of DVT in the range of 5% to 15%. Prophylaxis clearly provides an increment of improvement over patients without prophylaxis, and surveillance, in the very high-risk groups, will provide an additional increment of improvement. That is what we are seeing here. What we are struggling with in the framework of the existing data here is to identify which subpopulations of patients will achieve the additional benefit of surveillance and how effective patient selection and interval structure will improve the cost-effectiveness of surveillance programs.

Coagulation abnormalities were not specifically studied in a prospective fashion. Isolated individuals who developed unsuspected DVT had the usual coagulation workup. However, as you can see from the high incidence of malignancies and lower-extremity paralysis in patients with DVT, it was felt that in most of these cases, there was a clear, predisposing factor to the development of the DVT and that further diagnostic evaluation was unlikely to be helpful.

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