Tracking the Uptake of Evidence

Two Decades of Hospital Practice Trends for Diagnosing Deep Vein Thrombosis and Pulmonary Embolism

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Background: Advances in clinical research methods have led to prospective randomized controlled (level 1) clinical studies evaluating diagnostic modalities resulting in a paradigm shift in the literature for diagnosing deep vein thrombosis (DVT) and pulmonary embolism (PE). To assess whether these advances correlate with clinical practice, we analyzed 21-year trends in diagnostic testing for patients with venous thromboembolism.

Methods: We used discharge data from the National Hospital Discharge Survey (1979-1999) to determine DVT and PE cases annually. Procedure fields were screened to determine patients who had DVT or PE or who underwent venography, arteriography of the pulmonary arteries, pulmonary scintigraphy, or DVT ultrasonic scanning. Searching EMBASE, MEDLINE, and the American Thoracic Society guidelines, a literature-based time line of level 1 studies was derived and juxtaposed against trends and procedure use.

Results: Improved diagnostic tests resulted in diagnostic changes in patients with suspected venous thromboembolism. These observed changes correlated over time in subsequent years with level 1 studies. Diagnostic DVT approaches showed an initial marked increased use of venography followed by a rapid decline that coincided with increased use of Doppler ultrasonography. Diagnostic approaches to PE were characterized by initial marked increases in lung scanning followed by a rapid decline as use of ultrasonography considerably increased and pulmonary angiography modestly increased.

Conclusions: Diagnostic approaches to DVT and PE have changed markedly during the past 2 decades, in temporal harmony with the evolving literature. Change in clinical practice occurs over years, and long-term follow-up is required to capture this change.

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Advances in clinical trial methods have led to a progression of clinical trials evaluating diagnostic\(^1\) and treatment modalities\(^2,3\) that have profoundly affected the clinical management of patients with venous thromboembolism. Large volumes of evidence have been generated during the past 2 decades by researchers in the clinical field of venous thromboembolism. In particular, rigorous prospective studies (level 1)\(^1,4,7\) have confirmed or refuted dogmatic approaches to the diagnosis of venous thromboembolism by evaluating a broad spectrum of randomized consecutive patients, using a definitive reference test, and interpreting the results of each test or outcome without knowledge of the other test findings. The result has been a paradigm shift in the literature toward more rigorous approaches to the diagnosis of deep vein thrombosis (DVT) and pulmonary embolism (PE). Outcome studies, with long-term follow-up to determine the safety of withholding treatment in patients with negative results, have allowed refinement of the diagnostic pathway.\(^1,8\)

Although we have a general sense that diagnostic approaches have changed during the past 2 decades, the evolution of diagnostic testing for DVT and PE has not been clearly documented. Furthermore, the association of key new evidence in the peer-reviewed literature with changes in the use of diagnostic tests for PE and DVT has not been documented. This question is of considerable relevance because previous research in other areas has demonstrated marked delays between the appearance of definitive new evidence and its application by practicing clinicians.\(^9\) Definitive level 1 studies of DVT have demonstrated the importance of objective diagnostic tests.\(^1\) The first test to be evaluated was ascending contrast venography.\(^10,11\) Testing progressed to noninvasive diagnosis with impedance plethysmography and subsequently Doppler ultrasonogra-
much of it is available in hard copy. The NHDS is based on a national probability sample of discharges from noninstitutional hospitals exclusive of federal, military, and Department of Veterans Affairs hospitals, located in the 50 United States and the District of Columbia. A 3-stage sampling plan was introduced in 1988 and replaced an earlier, similarly designed 2-stage sampling plan. For both designs, there is a probability of sample hospitals and a systematic sampling procedure to select discharges within hospitals. The changes introduced with the 1988 redesign do not compromise the ability to conduct trend analysis.

First-Stage Sampling—Primary Sampling Units

There were 112 primary sampling units composed of counties, groups of counties, county equivalents (such as parishes and independent cities), or towns and townships.

Second-Stage Sampling—Hospitals

Hospitals in the primary sampling unit that had 1000 or more beds were always selected for inclusion in the survey and were termed "certainty hospitals." All other hospitals were selected using systematic random sampling. These were selected from the primary sampling units with a probability proportional to their annual number of discharges.

Third-Stage Sampling—Discharges

A sample of discharges from each hospital was selected using a systematic random sampling technique.

**METHODS**

**DATA SOURCE**

Data from the NHDS were used for this study. The NHDS database includes a broad mix of teaching and community hospitals. Data from this study are available on CD-ROM, and much of it is available in hard copy. The NHDS is based on data abstracted from a national probability sample of discharges from short-stay, noninstitutional hospitals, exclusive of federal, military, and Veterans Administration, in the 50 states and the District of Columbia. Only hospitals with an average length of stay for all patients of less than 30 days or those whose specialty is general (medical or surgical) or children's general, regardless of length stay, are included in the survey. Hospitals with an average length of stay of 30 days or more were excluded from the NHDS before 1988. Hospitals must have 6 or more staffed beds to be considered for the survey.

The number of responding hospitals and sampled patient abstracts in the NHDS for 1979 through 1999 ranged from 400 to 480 and from 181,000 to 307,000, respectively, representing approximately 8% of all hospitals and 1% of all discharges. The annual hospital response rate for the NHDS generally exceeds 90%. The survey includes all hospital discharges, including newborn infants and patients who died in the hospital.

The survey design, sampling, and estimation procedures were planned to produce calendar-year estimates. Trained medical personnel coded diagnoses and procedures using the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM). A minimum of 1 and a maximum of 7 diagnostic codes were assigned for each sample abstract. If an abstract included surgical or diagnostic procedures, a maximum of 4 procedure codes was assigned.

**REFERENCE**

References 11-17, 47, 50-52, 56-58, 60-72.

**NHDS SAMPLING SCHEME**

The NHDS is based on a national probability sample of discharges from noninstitutional hospitals exclusive of federal, military, and Department of Veterans Affairs hospitals, located in the 50 United States and the District of Columbia. A 3-stage sampling plan was introduced in 1988 and replaced an earlier, similarly designed 2-stage sampling plan. For both designs, there is a probability of sample hospitals and a systematic sampling procedure to select discharges within hospitals. The changes introduced with the 1988 redesign do not compromise the ability to conduct trend analysis.

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**Third-Stage Sampling—Discharges**

A sample of discharges from each hospital was selected using a systematic random sampling technique.

**ESTIMATION PROCEDURES**

Estimates of total numbers of patients with DVT, patients with PE, and diagnostic tests performed in the entire United States were derived from the number of sampled patients with DVT, the number of sampled patients with PE, and the number of diagnostic tests performed in sampled patients. This estimating was done using a multistage estimation procedure that produces essentially unbiased national estimates and has 3 basic components: inflation by reciprocals of the probabilities of sample selection, adjustment for nonresponding hospitals and for missing discharges within hospitals, and population weighting ratio adjustments. As the statistics from the survey are based on a sample, they may be different from the figures that would have been obtained if a complete census had been taken.

**IDENTIFICATION OF VENOUS THROMBOEMBOLISM CASES**

All available diagnostic code fields were screened for specific codes to identify patients with DVT or PE. Since 1979, the ICD-9-CM has been used for classifying diagnoses and procedures in the NHDS. Although the ICD-9-CM has been modified annually, the diagnostic codes for PE and infarction and phlebitis and thrombophlebitis of deep vessels of the lower extremities have changed little. The specific ICD-9-CM codes used for identification of patients with PE are 415.1, 634.6, 635.6, 636.6, 637.6, 638.6, and 673.2. The ICD-9-CM codes used for identification of patients with DVT are 451.1, 451.2, 451.8, 451.9, 453.2, 453.8, 453.9, 671.3, 671.4, and 671.9. Five-digit codes such as 415.11 (included under the code 415.1) were not listed separately, as they were included under the corresponding 4-digit codes.
IDENTIFICATION OF DIAGNOSTIC PROCEDURES FOR VENOUS THROMBOEMBOLISM

Patients who underwent diagnostic procedures for DVT or PE were identified by screening the following procedure codes: 88.66—phlebography of femoral and other lower extremity veins, 88.43—arteriography of pulmonary arteries, 92.15—pulmonary (radioisotopic) scan, and 88.77—DVT ultrasonic scanning.

STATISTICAL ANALYSIS AND METHODOLOGICAL CONSIDERATIONS

Descriptive statistics were used to graphically display trends over time in case volumes and number of diagnostic tests performed. These graphs showed estimated numbers of cases or diagnostic tests performed in the United States rather than numbers of sampled cases or procedures. It is recognized, however, that hospital discharge data incompletely capture many diagnoses and procedures. Therefore, trends in the relative number of patients with DVT or PE and trends in the relative use of specific diagnostic tests are the focus. Methodological issues, including the phenomenon of diagnosis related group (DRG) "creep,"22 change in the ICD-9-CM system, and the issue of sensitivity and specificity93 for capturing specific diagnoses and procedures, are discussed.

Linear regression analyses were used to calculate the slopes of selected linear segments of the curves describing the data.94 Pearson correlation analyses were performed for the same linear segments to assess the extent of dispersion of points around the regression lines.95 More complex equations to describe the curves were explored, but the fit of these curves never surpassed that of the linear analysis of selected segments. Differences in the number of diagnostic tests performed over time were assessed using t tests and analysis of variance.95

CHRONOLOGY OF EVIDENCE IN THE LITERATURE

The range of publication years of level 1 studies* that describe the validity of diagnostic tests and confirm their clinical outcomes was illustrated as timelines on the graphs describing the trends in the use of these tests.

MEDLINE and EMBASE literature searches were performed. The American Thoracic Society guidelines,4 which categorized diagnostic studies into level 1 or not, were also used as an external reference source. Rigorous prospective level 1 studies are key to understanding the role of each diagnostic test, as these prospective studies are meticulously designed to avoid bias.

RESULTS

The 21-year trends in the number of patients diagnosed as having DVT or PE are shown in Figure 1. For DVT, the trend was one of relative stability between 1979 and 1989, followed by an increase between 1989 and 1999. For this latter period, a significant upward linear trend was shown (slope, +15817 patients per year; r=0.978; P<.001). The trends for PE were somewhat different, with an initial decrease in cases between 1979 and 1989, followed by an increase between 1989 and 1999. Again, a significant linear trend for this latter period was shown (slope, +3446 patients per year; r=0.804; P<.003), although the increasing slope was less than that for DVT.

*Trends for acute pulmonary embolism for the period 1989-1999 are shown in Figure 1. For DVT, the number of recorded venograms remained low and relatively constant. Reflecting these divergent trends, there was a strong negative correlation between the frequency of venous ultrasound exami-
The 21-year trends in the use of diagnostic tests for PE, namely, V/Q lung scanning, pulmonary angiography, and Doppler ultrasonography, are shown in Figure 3. The use of V/Q lung scanning between 1979 and 1982 was relatively constant. Between 1982 and 1986, there was a sharp increase in the use of V/Q lung scans (slope, +2.4430 procedures per year; \( r = 0.986; P < .001 \)). This coincided temporally with a rapid rise in use of Doppler ultrasound.

The use of pulmonary angiography increased gradually and linearly for the entire 21 years (slope, +570 procedures per year; \( r = 0.876; P < .001 \)). In the latter years studied (1986-1999), there was a negative correlation between the frequency of V/Q scanning and pulmonary angiography (\( r = -0.567; P = .04 \)).

The corresponding chronology of evidence for the diagnosis of PE is depicted by the open and shaded timelines in Figure 3. Initial level 1 studies that contributed to the open timeline used pulmonary angiography as a definitive reference standard test. These studies confirmed the need for objective testing of the lungs for pulmonary embolism (V/Q lung scan) and the lower extremity deep vein thrombosis and showed limitations of V/Q lung scanning, which were confirmed in 1985 and 1990, indicating a more selective role for V/Q lung scanning. The lower time line (shaded rectangle) shows the interval during which level 1 studies were published (1990-1998), which further validated the selective role of V/Q lung scanning and the role of noninvasive leg testing in patients with suspected pulmonary embolism. The role and value of Doppler ultrasonography was confirmed in 1996 and 1998. The dates of the publications are shown by the vertical lines, and reference numbers are indicated at the base of the vertical lines.

TRENDS FOR THE DIAGNOSIS OF DVT

The 21-year trends in the use of diagnostic tests for PE, namely, V/Q lung scanning, pulmonary angiography, and Doppler ultrasonography, are shown in Figure 3. The use of V/Q lung scanning between 1979 and 1982 was relatively constant. Between 1982 and 1986, there was a sharp increase in the use of V/Q lung scans (slope, +24.430 procedures per year; \( r = 0.986; P = .002 \)). A sharp linear decrease occurred between 1986 and 1999 (slope, -7.893 procedures per year; \( r = -0.986; P < .001 \)). This coincided temporally with a rapid rise in use of Doppler ultrasound.

The use of pulmonary angiography increased gradually and linearly for the entire 21 years (slope, +570 procedures per year; \( r = 0.876; P < .001 \)). In the latter years studied (1986-1999), there was a negative correlation between the frequency of V/Q scanning and pulmonary angiography (\( r = -0.567; P = .04 \)).

The corresponding chronology of evidence for the diagnosis of PE is depicted by the open and shaded timelines in Figure 3. Initial level 1 studies that contributed to the open timeline used pulmonary angiography as a definitive reference standard test. These studies confirmed the need for objective testing of the lungs for PE and the lower extremity for DVT.97,98 These level 1 studies showed that V/Q lung scanning alone did not give a definitive diagnosis in many patients97,90 and that diagnostic leg testing was valuable adjunct,97,98 and that pulmonary angiography was necessary in selected patients.97,98

CLINICAL OUTCOMES STUDIES

Rigorous level 1 clinical trials assessing clinical outcomes using long-term follow-up confirmed the clinical value of serial noninvasive leg testing in patients with DVT55-72 (Figure 2) or PE56-58 (Figure 3). The findings of these studies correlate with the continued increased and ultimately stable use of Doppler ultrasonography.

Our 21-year analysis indicates that the sequential introduction of improved diagnostic approaches based on rigorous clinical research is reflected in profound and appropriate changes in hospital-based clinical practice for patients with suspected venous thromboembolism in the United States. Although marked delays have been observed in the uptake of evidence in other clinical areas,9 and the phenomenon of “clinical inertia”93 is well recognized, our findings point to a clear response by clinicians to the appearance of definitive evidence.

Changes in the frequency of use of venography, Doppler ultrasonography, and V/Q lung scanning are not attributable to changes in the frequency of diagnosis of PE and DVT, as trend curves for procedure use (Figures 2 and 3) do not correlate with trend curves depicting disease frequency (Figure 1).

Contrast-enhanced spiral computed tomography emerged as a diagnostic test for PE in the 1990s56-58. Because this test became widely available only in the late 1990s, it is unlikely that its use has been indirectly captured by our trend analysis, although an effect in the late 1990s cannot be excluded.

Some methodological issues require consideration. Important issues include sensitivity and specificity93 of the NHDS summary sheet for capturing diagnostic test use, the phenomenon of DRG creep,94 and changes over time in the ICD-9-CM coding system. The specificity of ICD-9-CM coding is high. Thus, most procedures that
were coded in discharge abstracts actually occurred. The frequencies reported, however, are underreported because of the imperfect sensitivity of coding for capturing diagnostic procedure occurrence.93 The consequence of lower sensitivity is that the absolute values shown on the trend curves in Figures 1 through 3 are an underestimate of the actual values. In contrast, the directional trends and relative positions of the curves described herein are likely to be correct. The potential for variation in sensitivity of coding over time represents a possible threat to the validity of our findings, and, in particular, 2 phenomena may have introduced variability into the sensitivity of coding: DRG creep and changes over time to the ICD-9-CM coding system. In the early 1980s, the Health Care Financing Administration introduced DRGs as a mechanism for reimbursing hospitals providing care to Medicare recipients. Hospital administrations rapidly recognized that reimbursement was directly linked to the extent of coding for individual patients. The phenomenon of DRG creep is thus an artifact of coding that might have increased the sensitivity of coding when this method of reimbursement was introduced. Despite the potential for DRG creep in our findings, we see that increases in the use of certain diagnostic tests in the mid-1980s coincided with the appearance of published evidence that likely explains these increases. Furthermore, the use of some diagnostic tests declined in the middle to late 1980s. These observations, therefore, suggest that DRG creep is unlikely to be a major contributor to the findings in Figures 2 and 3. As for the issue of changes over time to the ICD-9-CM coding system, there were no confounding changes to the coding for PE, DVT, or associated diagnostic tests during the 21 years studied. Thus, it is unlikely that changes to the ICD-9-CM perturbed our findings. A minor issue is that a minimal number of diagnostic tests were obtained for atypical reasons, including V/Q lung scanning before thoracic surgery and pulmonary angiography for chronic pulmonary hypertension.

Other factors contributing to the overall trends or their relationships are the availability of new diagnostic technology, peer example, and the general literature. Although many of the changes in the diagnostic approach over time are generally useful, there remains considerable room for improving the diagnostic approach to DVT and PE.

In summary, there were dramatic increases and reductions in the use of diagnostic tests between 1979 and 1999 that reflect the evolving paradigms of care for venous thromboembolism. The changes observed correlate over time with the results of rigorous level 1 diagnostic studies. Generally speaking, there has been considerable skepticism about the impact of evidence on clinical practice. Our 21-year perspective on diagnostic approaches to venous thromboembolism indicates that the apparently disappointing impact of various approaches to continuing medical education may reflect an inadequate interval of follow-up rather than failed application of the published evidence. Our observations, based on a US-wide hospital discharge survey, indicate that changes in clinical practice occur over many years and long-term follow-up is required to capture these changes.

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