The purpose of clinical pathways is to reduce resource utilization and therefore costs, while maintaining or improving overall clinical outcomes.\textsuperscript{1,3} There are various clinical pathways known by many names, including critical paths, care plans, and clinical pathways. Critical pathways were first used in industry in the 1950s and were then adapted for healthcare in the 1980s. Over 1995 and 1996, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) set standards for clinical healthcare delivery.\textsuperscript{4} Hospitals have accepted that clinical pathways and their multidisciplinary approach to patient care provide for better clinical outcomes and better quality of care at lower cost.\textsuperscript{5-10}

In Taiwan, major reforms to the healthcare system were implemented in March 1995. The prospective payment system introduced has required administrators to provide effective patient care with finite resources, and clinical pathways have been the favored strategy of hospitals. In 1997, 26 lobectomy patients had a mean length of stay of 37.5 ± 6.18 days, and 18% were readmitted. Factors affecting clinical pathway success were preoperative days ($p < 0.001$), postoperative days ($p = 0.033$), spirometry usage ($p = 0.043$), and patient education ($p = 0.02$). The clinical pathway was used to reduce mean hospital costs by 16% for lobectomy.

**Conclusions.** Length of hospital stay, readmission rates, spirometry usage, patient education, and costs benefited from clinical care pathway use. Factors critical to success appear to be multidisciplinary team work and communication. [Chin Med J (Taipei) 2002;65:7-12]
monary lobectomy patients. Two recent articles concluded that clinical pathways in major thoracic surgery are effective in reducing length of stay (LOS), controlling costs, and assuring quality of outcome. Consequently, this study was motivated by the desire to establish a pulmonary lobectomy clinical pathway for use in Taiwan and to assess selected clinical outcomes including preoperative days, postoperative days, LOS, intensive care unit (ICU) stay, preoperative education, postoperative education, spirometry usage per patient per day, early readmission rates and cost.

**Methods**

**Description of institution**

The study was performed at a large community-based teaching hospital that provided care primarily for military personnel and their families in Taipei, Taiwan. Most patients were covered by national health insurance. Physicians and medical students were involved in patient care.

**Clinical pathway**

The Program Evaluation Review Technique (PERT) was first utilized in healthcare in the 1980s to create a critical pathway for the New England Medical Center Hospitals and Center for Case Management. Luttman et al described PERT as comprising five basic phases: (1) construction of a network flow diagram; (2) collection of project activity, caregiver activity and patient activity times; (3) calculation of the activity time; (4) analysis of variances from the clinical pathway; and (5) establishment of the clinical pathway. In this study, PERT was used to analyze variances from the clinical pathway. First, Zander’s categories (consultations, tests, treatment, medication, mobility, diet/nutrition, discharge planning, and patient education) were used by the research team for collection of retrospective data documenting the activities and progress of the 26 control patients. Following this, the team designed a network flow diagram indicating the anticipated time required to complete each activity. Next, the caregiver and patient activity times for each subject were derived or estimated from historical data. Then, activity times were calculated.

Fig. 1. PERT network for the pulmonary lobectomy clinical pathway. Large arrow represents clinical pathway and small arrow represents other activity pathways.


\[
2.100.1 \quad 1.17 \\
4.150.1 \quad 1.83 \\
8.500.4 \quad 5.33 \\
4.267.0 \quad 2.45 \\
6.200.1 \quad 2.54
\]

\[
E(t_i) = \frac{(t_o + 4t_m + t_p)}{6}.
\]

tp = most pessimistic completion time; tm = most likely time; to = estimates of most optimistic; E(t_i): expected activity time.
lated and analyzed from the clinical pathway. Activity times were analyzed using the following three estimates: the optimistic time (to), the most likely time (tm) and the pessimistic time (tp). The PERT formula replaces the values of the constant activity time used in the clinical pathway with an “expected” (E) activity time (ti). The standard deviation for each expected activity time in the formula was calculated using the following approximation:

\[
E(t_i) = \frac{(to + 4tm + tp)}{6}
\]

\[
S(t_i) = \frac{(tp - to)}{6}
\]

The table below illustrates the expected activity times (days) and standard deviation for each activity.

<table>
<thead>
<tr>
<th>Number</th>
<th>Activity description</th>
<th>tp</th>
<th>to</th>
<th>tm</th>
<th>E(ti)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,2)</td>
<td>Admission from outpatient clinic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2,3)</td>
<td>Routine admission and special exam</td>
<td>2</td>
<td>1</td>
<td>1.00</td>
<td>1.17</td>
<td>0.03</td>
</tr>
<tr>
<td>(3,4)</td>
<td>Preoperative time</td>
<td>4</td>
<td>1</td>
<td>1.50</td>
<td>1.83</td>
<td>0.25</td>
</tr>
<tr>
<td>(4,5)</td>
<td>Removal of 1\textsuperscript{st} chest tube</td>
<td>8</td>
<td>4</td>
<td>5.00</td>
<td>5.33</td>
<td>0.44</td>
</tr>
<tr>
<td>(5,6)</td>
<td>Free drainage of 2\textsuperscript{nd} chest tube</td>
<td>4</td>
<td>0</td>
<td>1.33</td>
<td>1.55</td>
<td>0.44</td>
</tr>
<tr>
<td>(5,7)</td>
<td>Removal of 2\textsuperscript{nd} chest tube</td>
<td>4</td>
<td>0</td>
<td>2.67</td>
<td>2.45</td>
<td>0.44</td>
</tr>
<tr>
<td>(7,8)</td>
<td>Discharge</td>
<td>6</td>
<td>1</td>
<td>2.00</td>
<td>2.54</td>
<td>0.69</td>
</tr>
</tbody>
</table>

1: Outpatient Clinics; 2: Chest Surgery; 3: Routine admission and Special examination; 4: Operation/Intensive Unit; 5: Removal of 1\textsuperscript{st} chest tube; 6: Free drainage of 2\textsuperscript{nd} chest tube; 7: Removal of 2\textsuperscript{nd} chest tube; 8: Discharge; 9: Emergency Unit; 10: Chest Medical Unit; 11: Routine admission & Special exam in Chest Medical Unit; tp = most pessimistic completion time; tm = most likely time; to = estimates of most optimistic; E(t_i) = expected activity time.; E(t_i) = (to + 4tm + tp)/6.

Next, a standardized pulmonary lobectomy clinical pathway was based on these data for each activity. The PERT diagram was developed and established (Fig. 1 and Table 1). A clinical pathway coordinator worked closely with clinical staff, helping to facilitate implementation of the clinical pathway. Project details were distributed to the Chest Surgery units and physicians whom we believed would be involved in the pilot study. Frequent discussions were required to address concerns of individuals whose daily work was influenced by the pathways. Six months later, the research team decided to start collecting data for the clinical pathway (experimental) group.

### Study design

A total of 40 cases were enrolled during the study period. The data were collected from patients whose procedures were categorized as ICD-9 (International Classification of Disease) code 244 (pulmonary lobectomy). Twenty-six cases comprising the control group had been admitted between January 1, 1997, and November 31, 1997, before the pathway had been implemented. The fourteen cases in the experimental group were admitted between July 1, 1998, and June 30, 1999, and were treated according to the clinical pathway. In-hospital demographics and procedures were summarized in the patient’s chart review. Data collected included: age, gender, preoperative days, intensive care unit length of stay, postoperative days, chest removal day, spirometry, and age, top ics covered in patient education, length of stay in hospital, early readmissions, and cost.

Pilot study

The pathway was initiated in December 1997. Education was provided to medical, nursing, and other staff with 12 hours of training courses. All healthcare workers involved with pulmonary lobectomy patients were informed of the low pathway guidelines. A clinical pathway coordinator...
Statistical analysis

All activities undertaken during the patient’s treatment were listed in sequential order and analyzed by using the Student’s t-test to compare pairs of independent means for each variable. The $p$ value for statistical significance is 0.05.

Results

There were no significant differences between the two groups in patient age, sex, and diagnosis. The mean age for the control group was 58.5 years and the mean age for the experimental group was 62.4 years. The mean LOS was reduced 19.6 days ($p < 0.001$) in fiscal year 1998 after the clinical pathway was implemented (Table 2). There were significant reductions in the number of preoperative days (9.1 days) and postoperative days (9.1 days) after pathway implementation. Nurses covered more areas of preoperative and postoperative care ($p = 0.002$) and postoperative education ($p < 0.001$) after the clinical pathway was implemented. More patients in the experimental group used spirometry before surgery ($p = 0.043$) than patients in the control group. The experimental group had a significantly lower ($p < 0.001$) early readmission rate (0%) than the control group (18%). The mean cost per patient decreased from $187,649 to $157,281 (New Taiwan dollars) after the pathway was implemented. There were no differences in patient ICU stay duration or in the number of days chest tubes remained in place (Table 2).

Discussion

The results show that the 26 pulmonary lobectomy patients in the control group spent a mean of 13.4 days waiting for surgery and waited a mean of 23.8 days postsurgically before discharge. These patients tended to have a poorer quality of clinical care, in particular due to delays before consultations, blood checks, and extubation. With a clinical pathway, patients received more presurgical education and preparation and also received less postsurgical and discharge care. In contrast, the 14 patients following a clinical pathway showed reductions in preoperative stays and postoperative stays. One reason for the improvements could be that the use of PERT for establishing the clinical pathway helps physicians have a “big-picture” understanding of the treatment process and what stage a patient should be at on a given day. PERT has proven valuable to the clinical pathway movement. After reviewing 46 articles discussing clinical pathways, Pearson et al. (1995) concluded that PERT was the most useful tool available for the assessment of pathways.

Since its introduction in this hospital, the lobectomy clinical pathway has not only decreased length of stay, but also had further benefits. The clinical pathway significantly reduced the mean hospital stay.

Table 2. Pulmonary lobectomy patient data vs. clinical pathway

<table>
<thead>
<tr>
<th>Patient data</th>
<th>Group without CP N = 26</th>
<th>Group with CP N = 14</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean pre-OP days</td>
<td>13.4 ± 2.8</td>
<td>3.8 ± 2.1</td>
<td>4.460a</td>
</tr>
<tr>
<td>Mean post-OP days</td>
<td>23.8 ± 5.88</td>
<td>13.9 ± 4.43</td>
<td>2.23b</td>
</tr>
<tr>
<td>Mean LOS</td>
<td>37.5 ± 6.18</td>
<td>17.9 ± 4.68</td>
<td>4.198a</td>
</tr>
<tr>
<td>Mean ICU stay</td>
<td>4.9 ± 1.88</td>
<td>3.0 ± 1.88</td>
<td>0.975</td>
</tr>
<tr>
<td>Mean items of Pre-OP education</td>
<td>1.9 ± 0.26</td>
<td>2.9 ± 0.28</td>
<td>3.818a</td>
</tr>
<tr>
<td>Mean items of Post-OP education</td>
<td>2.2 ± 0.9</td>
<td>5.5 ± 0.24</td>
<td>4.67a</td>
</tr>
<tr>
<td>Mean spirometer usage/patient/day</td>
<td>0.0</td>
<td>2.0 ± 0.88</td>
<td>2.248b</td>
</tr>
<tr>
<td>Mean cost/patient</td>
<td>$187,649</td>
<td>$157,281</td>
<td>8.517a</td>
</tr>
<tr>
<td>Early readmission</td>
<td>18%</td>
<td>0%</td>
<td>2.145a</td>
</tr>
</tbody>
</table>

CP = Clinical pathway, $^a p < 0.05$, $^b p < 0.01$. No difference before groups at Mean ICU stay. Pre-OP days = Preoperative days; Post-OP days = Postoperative day; LOS = Length of stay; Pre-OP education = Preoperative education; Post-OP education = Postoperative education; Spirometer usage/patient/day = Spirometer usage per patient per day; Cost/patient = Cost per patient.
clinical costs for lobectomy procedures. Most of the to tal hos pi tal costs sav ing translating from hos pi tal stay re duction. The re ad mis sion rate showed a sig nifi cant de crease from 18% for the con trol group down to 0% for the path way group. Hos pi tal re ad mis sion data can help to iden tify ar eas of med i cal care re quiring im- prove ment and to eval uate the im pact of im ple mented nurs ing strategies.5,10 The pro cess in her ent in the de vel opment of a clin i cal path way also im proves col labora tion be tween health care team mem bers.18,19

The pul mo nary lobectomy clin i cal path way de vel oped dur ing the study rec om mends early hos pi tal dis charge for pul mo nary lobectomy pa tients.10,11 As with guide lines for most hos pi tal pro cesses, the deter mi nant of best prac tice is to some extent the re duc tion in the num ber of pre op er a tive and post op er a tive days of stay.3,6 Some el ements of the clin i cal path way pro vide a sim ple but ef fec tive in flu ence on qual ity and ef fi ciency goals.7 As pre op er a tive phy si cians, an es the tists can im ple ment sav ings and cre ate value for their health care sys tem by par tic i panting in path way de vel opment.16 Clin i cal path ways stan dard ize prac tice and address variabil ity in prac tice by hav ing pro vid ers agree pro spec tively on a com mon reg i men of clin i cal in ter ven tions.5,9,17-20

It is gen erally ac cepted that suc cess ful im ple men ta tion of a clin i cal path way pro gram is crit i cally de pend ent on staff edu ca tion.16 In this study, edu ca tion was pro vided to med i cal staff over 12 hours of train ing during the path way stage. The re search team was re spon si ble for the de vel opment of clin i cal path ways for pa tient path way con tent and for mat, as well as for the vari ance-tracking pro cess. A path way coord inator pro vides on go ing guid ance to staff re garding path way re lated pro cesses. As Swan has con cluded, effective pathway edu ca tion re quires fore thought, plan ning, re source com mit ment, and ad min istrative sup port. It be gins be fore the de vel opment of the clin i cal content of the pathway and con tinues through out the path way im ple men ta tion pro cess and be yond.16

Lim i ta tions of this study in cluded the small num ber of pa tients un der go ing lobectomy and the fact that the study was se lec tive rather than ran dom com par ing a ret ro spec tive con trol group with a pro spec tive ex per i men tal group. Finally, it must be re mem bered that not all pa tients can be treated with a uni form path way, as each pa tient has unique prob lems and needs. The pul mo nary lobectomy clin i cal path way there fore serves as a guide to care de liv ery and out comes for the “aver age” pa tient, but can not re place the phy si cian’s abil i ty to ad dress in divid ual pa tient prob lems.

The use of a clin i cal path way for Tai wan ese lobectomy pa tients im proved ma sures of treat ment such as LOS, re ad mis sion days, cost, and care. Ap pli cation of PERT to the pul mo nary lobectomy clin i cal path way pa tients al lowed care to be stan dard ized, the length of stay re duced, and qual ity con trol pro cesses to be im ple mented, all im prov ing pa tient care. The suc cess of this method appears to be its multi -discipli nary ap proach, iden ti fi ca tion and con trol of high cost areas through out the hos pi tal iza tion pe ri oids, specific care within a stan dard ized time frame, and iden ti fi ca tion of re asons for pro longed pa tient stays.

References

5. Holtzman J, Bjerke T, Kane R. The ef fects of clin i cal path ways for pa tients re quir ing pro longed me chan i cal ven ti la tion. Crit Care Nurse 1997;17:70-5.
9. Ray mond B, Scott W, Mi chael L, Zab M. Im pact of clin i cal path way for Tai wan ese lobectomy pa tients im proved me sures of treat ment such as LOS, re ad mis sion days, cost, and care. Ap pli cation of PERT to the pul mo nary lobectomy clin i cal path way pa tients al lowed care to be stan dard ized, the length of stay re duced, and qual ity con trol pro cesses to be im ple mented, all im prov ing pa tient care. The suc cess of this method appears to be its multi -discipli nary ap proach, iden ti fi ca tion and con trol of high cost areas through out the hos pi tal iza tion pe ri oids, specific care within a stan dard ized time frame, and iden ti fi ca tion of re asons for pro longed pa tient stays.


