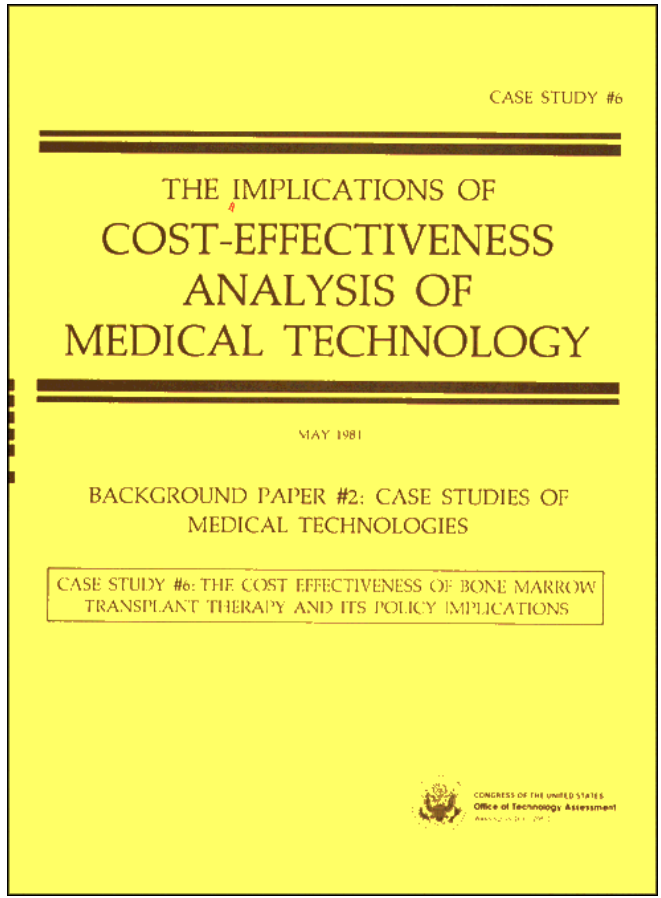
The Cost Effectiveness of Bone Marrow Transplant Therapy and Its Policy Implications

May 1981

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THE IMPLICATIONS OF COST-EFFECTIVENESS ANALYSIS OF MEDICAL TECHNOLOGY

MAY 1981

BACKGROUND PAPER #2: CASE STUDIES OF MEDICAL TECHNOLOGIES

CASE STUDY #6: THE COST EFFECTIVENESS OF BONE MARROW TRANSPLANT THERAPY AND ITS POLICY IMPLICATIONS

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OTA Background Papers are documents that contain information believed to be useful to various parties. The information undergirds formal OTA assessments or is an outcome of internal exploratory planning and evaluation. The material is usually not of immediate policy interest such as is contained in an OTA Report or Technical Memorandum, nor does it present options for Congress to consider.

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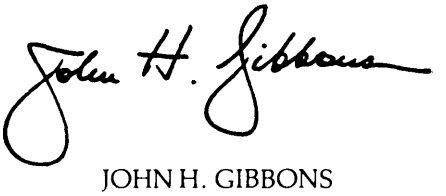
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Foreword

This case study is one of 17 studies comprising Background Paper #2 for OTA's assessment, The *lmplications of- Cost-Effectiveness Analysis of Medical Technology.* That assessment analyzes the feasibility, implications, and value of using cost-effectiveness and cost-benefit analysis (CEA/CBA) in health care decisionmaking. The major, policy-oriented report of the assessment was published in August 1980. In addition to Background Paper #z, there are four other background papers being published in conjunction with the assessment: 1) a document which addresses methodological issues and reviews the CEA/CBA literature, published in September 1980; 2) a case study of the efficacy and cost-effectiveness of psychotherapy, published in October 1980; 3) a case study of four common diagnostic X-ray procedures, to be published in summer 1981; and 4) a review of international experience in managing medical technology, published in October 1980. Another related report was published in September of 1979: *A Review of Selected Federal Vaccine and Immunization Policies.*

The case studies in *Background Paper #2: Case Studies of Medical Technologies* are being published individually. They were commissioned by OTA both to provide information on the specific technologies and to gain lessons that could be applied to the broader policy aspects of the use of CEA/CBA. Several of the studies were specifically requested by the Senate Committee on Finance.

Drafts of each case study were reviewed by OTA staff; by members of the advisory panel to the overall assessment, chaired by Dr. John Hogness; by members of the Health Program Advisory Committee, chaired by Dr. Frederick Robbins; and by numerous other experts in clinical medicine, health policy, Government, and economics. We are grateful for their assistance. However, responsibility for the case studies remains with the authors.



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Preface

This case study is one of 17 that comprise Background Paper #2 to the OTA project on the *Implications of Cost-Effectiveness Analysis* **of** *Medical Technology.* * The overall project was requested by the Senate Committee on Labor and Human Resources. In all, 19 case studies of technological applications were commissioned as part of that project. Three of the 19 were specifically requested by the Senate Committee on Finance: psychotherapy, which was issued separately as Background Paper #3; diagnostic X-ray, which will be issued as Background Paper #5; and respiratory therapies, which will be included as part of this series. The other 16 case studies were selected by OTA staff.

In order to select those 16 **case** studies, OTA, in consultation with the advisory panel to the overall project, developed a set of selection criteria. Those criteria were designed to ensure that **as a** group the **case** studies would provide:

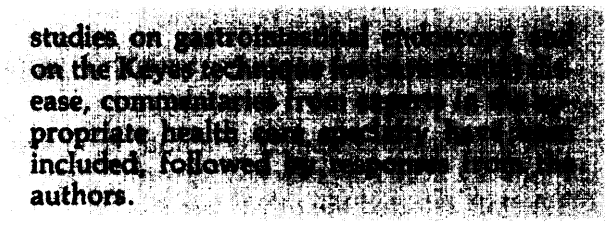
- examples of types of technologies by function (preventive, diagnostic, therapeutic, and rehabilitative);
- examples of types of technologies by physical nature (drugs, devices, and procedures);
- examples of technologies in different stages of development and diffusion (new, emerging, and established);
- examples from different areas of medicine (such as general medical practice, pediatrics, radiology, and surgery);
- examples addressing medical problems that are important because of their high frequency or significant impacts (such as cost);
- examples of technologies with associated high costs either because of high volume (for low-cost technologies) or high individual costs;
- examples that could provide informative material relating to the broader policy and methodological issues of cost-effectiveness or cost-benefit analysis **(CEA/CBA); and**
- examples with sufficient evaluable literature.

On the basis of these criteria and recommendations by panel members and other experts, OTA staff selected the other case studies. These 16 plus the respiratory therapy case study requested by the Finance Committee make up the 17 studies in this background paper.

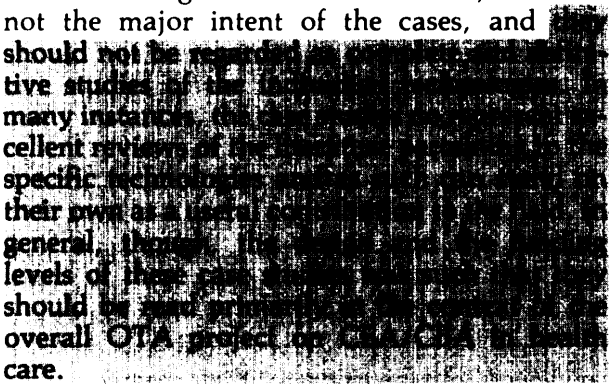
AII case studies were commissioned by OTA and performed under contract by experts in academia. They are authored studies. OTA subjected each case study to an extensive review process. Initial drafts of cases were reviewed by OTA staff and by members of the advisory panel to the project. Comments were provided to authors, along with OTA's suggestions for revisions. Subsequent drafts were sent by OTA to numerous experts for review and comment. Each case was seen by at least 20, and some by 40 or more, outside reviewers. These reviewers were from relevant Government agencies, professional societies, consumer and public interest groups, medical practice, and academic medicine. Academicians such as economists and decision analysts also reviewed the cases. In all, over 400 separate individuals or organizations reviewed one or more case studies. Although all these reviewers cannot be acknowledged individually, OTA is very grateful for their comments and advice. In addition, the authors of the case studies themselves often sent drafts to reviewers and incorporated their comments.

These case studies are authored works commissioned by OTA. The authors are responsible for the conclusions of their specific case study. These cases are not statements of official OTA position. OTA does not make recommendations or endorse particular technologies. During the various stages of the review and revision process, therefore, OTA encouraged the authors to present balanced information and to recognize divergent points of view. In two cases, OTA decided that in order to more fully present divergent views on particular technologies a commentary should be added to the case study. Thus, following the case

● Office of Technology Assessment, U.S. Congress, ***The Implications of Cost-Effectiveness Analysis*** **of** ***Medical Technology,*** GPO stock No. **052-003 -00765-7** (Washington, D. C.: U. S, Government printing Office, August 1980),



The case studies were selected and designed to fulfill two functions. The first, and primary, purpose was to provide OTA with specific information that could be used in formulating general conclusions regarding the feasibility and implications of applying CEA/CBA in health care. By examining the 19 cases as a group and looking for common problems or strengths in the techniques of CEA/CBA, OTA was able to better analyze the potential contribution that these techniques might make to the management of medical technologies and health care costs and quality. The second function of the cases was to provide useful information on the specific technologies covered. However, this was not the major intent of the cases, and



Some of the case studies are formal CEAS or CBAS; most are not. Some are primarily concerned with analysis of costs; others are more concerned with analysis of efficacy or effectiveness. Some, such as the study on end-stage renal disease, examine the role that formal analysis of costs and benefits can play in policy formulation. Others, such as the one on breast cancer surgery, illustrate how influences other than costs can determine the patterns of use of a technology. In other words, each looks at evaluation of the costs and the benefits of medical technologies from a slightly different perspective. The reader is encouraged to read this study in the context of the overall assessment's objectives in order to gain a feeling for the potential role that CEA/CBA can or cannot play in health care and to better understand the difficulties and complexities involved in applying CEA/CBA to specific medical technologies.

The 17 case studies comprising *Background Paper #2* (short titles) and their authors are:

Artificial Heart: Deborah P. Lubeck and John P. Bunker

Automated Multichannel Chemistry Analyzers: Milton C. Weinstein and Laurie A. Pearlman



Breast Cancer Surgery: Karen Schachter and Duncan Neuhauser

Cardiac Radionuclide Imaging: William B. Stason and Eric Fortess

Cervical Cancer Screening: Bryan R. Luce

Cimetidine and Peptic Ulcer Disease: Harvey V. Fineberg and Laurie A. Pearlman

Colon Cancer Screening: David M. Eddy

CT Scanning: Judith L. Wagner

Elective Hysterectomy: Carol Korenbrot, Ann B. Flood, Michael Higgins, Noralou Roos, and John P. Bunker

End-Stage Renal Disease: Richard A. Rettig

Gastrointestinal Endoscopy: Jonathan A. Showstack and Steven A. Schroeder

Neonatal Intensive Care: Peter Budetti, Peggy McManus, Nancy Barrand, and Lu Ann Heinen

Nurse Practitioners: Lauren LeRoy and Sharon Solkowitz

Orthopedic Joint Prosthetic Implants: Judith D. Bentkover and Philip G. Drew

Periodontal Disease Interventions: Richard M. Scheffler and Sheldon Rovin

Selected Respiratory Therapies: Richard M. Scheffler and Morgan Delaney

These studies will be available for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Call OTA's Publishing Office (224-8996) for availability and ordering information.

Case Study #6

The Cost Effectiveness of Bone Marrow Transplant Therapy and Its Policy Implications

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Case Study #6:

The Cost Effectiveness of Bone Marrow Transplant Therapy and Its Policy Implications

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INTRODUCTION

The diffusion of biomedical technology in the United States has had a striking impact on health care personnel, institutions, and costs. The rate at which biomedical innovations are diffused within the health care system, although an important characteristic of that system, is also one about which relatively little is known. The diffusion of some innovations (e. g., certain anticancer drugs) is allegedly too slow, while the diffusion of others (e.g., coronary bypass surgery and total body scanners) is allegedly too rapid, We have little knowledge about determining how and why technological innovations actually diffuse and little experience in specifying socially optimal rates of diffusion for various types of innovations. Focusing on one new technology—bone marrow transplantation (BMT)–this stud, presents both a critica] analysis of the technology itself and policy options that would strengthen control over the rate of technological diffusion.

THE DIFFUSION OF NEW TECHNOLOGY

The increasing allocation of resources to the health care sector of the economy and health care cost inflation resulting from the rapid diffusion of certain biomedical technologies have become issues of urgent public policy debate at all levels of government: Federal, State, and even local. Clearly, the widespread—and possibly excessive—diffusion of some medical technologies has been encouraged by the current public and private methods of financing medical care. Financial reimbursement of new technologies by third-party payers (including medicaid and medicare) is crucial for the providers of health care services. One would expect that, given their importance in influencing the health care system, decisions to reimburse for a new technology would be complex, based on a number of evaluative criteria, In fact, however, they have not been. No formal process, public or private, to ensure that studies of cost and effec-

tiveness of new technologies are conducted and that prospective data are collected and analyzed has existed.

If the consumption and production of health services were subject to the same forces present in competitive markets, the problem of widespread diffusion of medical technology and its impact on the quality and cost of health care services would not be an issue. In a perfectly competitive market, the price of a service falls to a point where supply recedes to meet demand at a market-clearing price. However, the market for health care services does not function in this manner. Third-party financing has expanded the demand for health services and has made both consumers and providers decreasingly sensitive to price. In addition, factors such **as** the importance of Government research in creating biomedical innovations, as well as the frequent inability of consumers to evaluate the need for or relative success of a new biomedical technology, militate against the application of classical market constraints to the adoption of technology in the health care sector.

The effects of widespread diffusions of new medical technologies have surfaced as causal factors in the escalation of health care costs. Excessive supply of new technologies in the health care sector may result in the underutilization of existing technologies and personnel. With a rapid rate of technological innovation, the rate of technological obsolescence becomes a significant concern. To make matters worse, an extrapolation of a common law of technological diffusion and use (Roemer's Law) would propose that the availability of new medical technologies creates demand for, and hence generates use of, these technologies. If mere availability defines the use of new technologies, then, in addition to the problem of underutilization of existing technologies, there may be overutilization of new technologies.

A number of new biomedical technologies now being used on a small scale may shortly present themselves as widely useful modes of medical treatment. One such technology is BMT for the treatment of aplastic anemia and acute leukemia. It would appear useful to conduct a social cost-effectiveness analysis (CEA) of BMT therapy now, while the technology is still in an early stage. Control and restriction of the service to **a** limited number of institutions are still feasible (if desirable) at present, but in a few years might not be.

Examining BMT therapy is significant for a variety of reasons:

- BMT is an extremely expensive procedure.
- The question arises whether BMT therapy is an effective treatment in terms of patient survival and quality of such survival.
- There is a greater demand for BMT procedures than there are time, resources, and availability of payment mechanisms. [1]
- BMT programs require extensive and costly coordination of a number of different medical care services.
- The startup and capital acquisition costs of new programs are significant.
- BMT programs require specialized professional training of health care personnel because of the intensive nature of the technology.
- It appears that without information about the effectiveness of a new procedure such **as** BMT, physicians test the technology using a variety of methods to develop their own sense of its worth.

The process of information gathering by physicians may in itself contribute substantially to the inappropriate use and attendant high cost of the technology (7).

[1] Approximately 20 percent of patients referred to UCLA's Bone Marrow Transplantation Program are being turned away for lack of finances, beds, or manpower.

DESCRIPTION OF BMT THERAPY

BMT therapy is a relatively new medical technology used in the treatment of aplastic anemia and acute leukemia. In much the same way as a kidney transplant can replace a diseased kidney, transplanted bone marrow can replace a diseased bone marrow. The bone marrow is the site of production of red blood cells, white blood cells, and platelets. In the severe form of aplastic anemia, the bone marrow ceases to function. The patient becomes severely anemic and is susceptible to bleeding and infectious complications. In acute leukemia, a neoplastic disease, the bone marrow produces immature (malignant) white blood cells that replace normal marrow elements. Patients with severe aplastic anemia and patients with leukemia who are unresponsive to conventional therapy (discussed below) are potential candidates for BMT therapy.

The BMT procedure involves three phases. In the first phase, lasting 5 to 14 days, the bone marrow recipient is prepared for the graft. Immunosuppressive and cytotoxic chemotherapy are administered and irradiation is used to enable the recipient to accept the graft, to prevent graft rejection, and in cases of acute leukemia to eliminate residual leukemia.

In the second phase, bone marrow is procured from an HL-A* sibling donor and intravenously administered to the graft recipient. Donors and recipients of bone marrow transplants must be matched at the HL–A locus, the complex of genes that determine the compatibility of tissue transplants. A second test, important in the selection of donors for BMT, is the mixed leukocyte culture test in which donor and recipient leukocytes are cultured together to determine their ability to recognize each other as foreign (3).

The third phase is a period of waiting for the bone marrow to engraft and function normally in the recipient. During the time required for engraftment (approximately 2 to 4 weeks), the graft recipient is vulnerable to infection, bleeding, severe weight loss, rejection of the graft, and graft-versus-host disease (GvHD). GvHD occurs in approximately 70 percent of BMT patients. The transplanted lymphocytes recognize the host (i. e., patient) as foreign and attack the patient's skin, liver, and intestine. Thus, large areas of the patient's skin maybe damaged and the patient may develop severe diarrhea. Severe jaundice with abnormal liver function tests is also common. GvHD varies from a transient, mild skin rash to a rapid] y progressive fatal disease. If the marrow engrafts and the patient survives the immediate posttransplant period (first 3 to 6 weeks), he or she faces another set of complications, including GvHD and interstitial pneumonia. Interstitial pneumonia *occurs* in 60 percent of BMT patients, typically 4 to 6 weeks post transplant. The disease progresses rapidly and is fatal in approximate] y 50 percent of cases.

*HL-A antigens, histocompatibility antigens on the surface of nucleated cells, are determined by a single major chromosomal locus, the HL-A locus; they are important in cross-matching for transplantation procedures.

DESCRIPTION OF CONVENTIONAL THERAPY AND OUTCOMES

For purposes of analyzing the effectiveness of BMT therapy, one should compare results obtained in patients treated with BMT therapy with results obtained in equivalent patients treated with conventional forms of therapy. In this case study, we consider only two diagnoses for which BMT or conventional treatment is administered, aplastic anemia and acute leu-

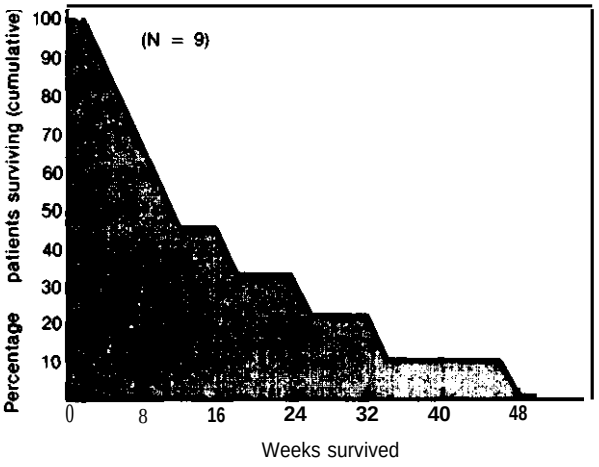
kemia. [2] Conventional therapy for aplastic anemia involves corticosteroids, androgens, and red blood cell and platelet transfusions. Conventional therapy for acute leukemia consists of various combinations of chemotherapy.

The data employed in our analysis to compare the effectiveness of BMT therapy and conventional therapy were abstracted from survival studies reported in the medical literature (8,9). Survival data were obtained on retrospective control groups of aplastic anemia and acute leukemia patients who would have received transplants had a suitable bone marrow donor been available. The patients in the control groups were reportedly matched for known prognostic factors with BMT patients and were cared for by a single group of physicians.

The actuarial survival curves for aplastic anemia and leukemia patients given conventional therapy are displayed in figures 1 and 2, respectively. As indicated, the outlook for patients with these diseases is very poor. All nine aplastic anemia patients represented in figure 1 died within 1 year of diagnosis; the median survival time from diagnosis was 2.5 months. None of the 37 acute leukemia patients represented in figure 2 survived more than 13 months post-relapse; the median survival was 4 months.

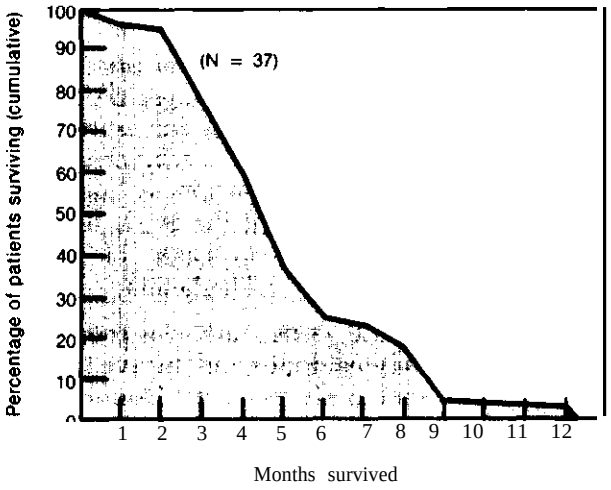
[2] BMT therapy is currently being used to treat a wide variety of blood disorders, but these other applications are excluded from this study because the programs are too new to allow analysis of time-series data.

Figure 1.—Actuarial Survival of Aplastic Anemia Patients Given Conventional Therapy



SOURCE UCLA Bone Marrow Transplant Team, "Bone Marrow Transplantation in Severe Aplastlc Anemia, " *Lancet* 229. October 1978

Figure 2.—Actuarial Survival of Acute Leukemia Patients Given Conventional Therapy



SOURCE UCLA Bone Marrow Transplant Team, "Bone Marrow Transplantation In Acute Leukemia. " *Lancret* 21197, December 1977

COST-EFFECTIVENESS ANALYSIS

Data

The source of data for the CEA of BMT therapy which follows is the UCLA Bone Marrow Transplantation Program. This program is the second largest of six BMT programs in the United States and performs about SO transplants a year. It is important to note that a BMT program is an enormous clinical effort which requires the coordination of many different professionals. At UCLA, the transplant team consists of clinicians from the departments of pediatrics, medicine, and surgery, clinical pathologists, geneticists, basic scientists from the departments of microbiology and immunology, and experts in tissue-typing and radiation.

The treatment protocol for BMT varies somewhat from center to center, although patient characteristics and selection criteria are generally uniform. However, it should be cautioned that a therapy as new as BMT is constantly being changed (e. g., recent changes have occurred in the choice of morbidities to be treated with BMT and the stage at which BMT is employed). Variation in experience over time within any one site, as well as variation across sites, is therefore to be expected. In addition, the number of patients treated in each individual center has been small. Evaluating a technology such as BMT therapy is a bit like taking a snapshot of a moving object—as soon as the picture is taken, it is different from the way it was. Nonetheless, evaluations are useful to monitor progress of technological development, as well as to indicate the appropriate timing for public policy intervention, such as third-party financing of care.

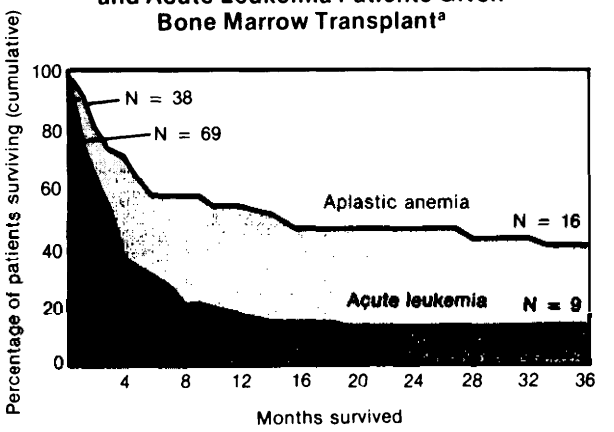
For purposes of our analysis, data were collected on 107 patients with aplastic anemia and leukemia who had been given BMT therapy at UCLA. The specific sources of the data were patients' medical records, the patient billing department at UCLA, and interviews with nursing and medical staff on the BMT team.

The actuarial survival curves for UCLA BMT patients with aplastic anemia and acute leukemia are shown in figure 3. As can be seen, the two curves are similar. For both groups of patients, the greatest risk of death occurs within the first 5 to 8 months after transplant. Patients who survive this period appear to stand an excellent chance of longer term survival.

Cost of BMT Therapy

The total cost of BMT treatment consists of: 1) direct costs, which are the medical costs; and 2) indirect costs, which are all other costs imposed on the patient and others. BMT patients and donors incur costs in both categories, because both patients and donors receive medical treatment and experience lost time. For the purposes of our analysis, patient charges were used as proxies for direct costs. The substitution of charges for costs was necessitated by the availability of data. However, since the policy implications of our study deal largely with reimbursement, charges are the relevant "cost" measures.

Figure 3.—Actuarial Survival of Aplastic Anemia and Acute Leukemia Patients Given Bone Marrow Transplant[a]



[a]Patients treated at UCLA's Bone Marrow Transplantation Program from Mar. 1 1974, to Aug. 31, 1978.

SOURCE: Based on data from UCLA's Bone Marrow Transplantation Program, Los Angeles, Calif , 1978.

In the case of the bone marrow donor and family, lost time is assumed to be valued at an average national wage rate. A potential long-term indirect benefit of BMT treatment, earnings of those patients who are able to return to work or other normal activities, would reduce the total net costs of treatment, especially if the proportion of patients able to return were large. However, the experience of the patient group at UCLA did not seem to warrant an attempt to estimate this earnings flow.

Charges were obtained from the UCLA Health Sciences Records System for every third BMT patient treated at UCLA between 1974 and 1978. The mean charge for BMT treatment (including hospital charges and professional fees), and indirect costs for patient, donor, and family are tabulated in table 1. The mean charges by detailed service category are shown in the tables in the appendix. These detailed mean charges for services reflect both the actual charge for a service and the probability of the service's *use, so* tabulated charges are not necessarily equal to actual charges. The difference in total cost of BMT therapy for the two morbidity groups,

Table 1.—Mean Total Cost of BMT Treatment[a]

Direct costs		
Patient:		
Hospital	$60,743[b]	
Professional fees	2,880[c]	
	$63,623	
Donor:		
Hospital (3 days)	$ 1,184[d]	
Professional fees	1,000	
Residential costs for 15 days at $35.00 per diem[e]	525	
	$ 2,709	
Total direct costs		$66,332
Indirect costs		
Patient[f]	$ 0	
Donor: 15 days, average cost $32.00 day[g]	480	
Family: 30 days, average cost $32.00 day	960	
	$ 1,440	
Total indirect costs		$ 1,440
Total cost (direct and indirect)		$67, 772

[a]Patients treated at UCLA's Bone Marrow Transplantation Program from Mar. 1, 1974, to Aug. 31, 1978.
[b]See table A-1 in the appendix.
[c]See table A-2 in the appendix.
[d]See table A-3 in the appendix.
[e]Nonlocal families must incur double these costs, while local patients and families will not incur them. The current mix at UCLA is approximately 50 percent in each category.
[f]Indirect patient costs are zero, because the patients are so ill that normal activities would not be undertaken.
[g]Based on average of $8,000/yr average income. Lost wages will be higher for out-of-town patients and less for local patients.

SOURCE: Calculations based on data from UCLA's Bone Marrow Transplantation Program, Los Angeles, Calif.

aplastic anemia and acute leukemia, was very small and was ignored in the calculations.

Because of the high early mortality rate among BMT patients, we were concerned that the mean direct costs in table 1, although representative of typical BMT patients, might not reflect costs of successful treatment: BMT survivors might undergo a longer period of treatment and hence incur higher charges than typical patients. To test this hypothesis, we obtained hospital and professional charges for every BMT patient treated at UCLA between January 1976 and August 1977 whose account was closed as of August 1977. We found that the mean charges for BMT patients who survived longer than 3 months were, in fact, slightly lower than the mean charges for all patients. The difference was approximately 2.4 percent.

Survivors	$56,206
Nonsurvivors	58,068
Weighted mean for all BMT patients	57,565

One explanation is that the length-of-treatment effect was countered and dominated by the intensity of treatment provided to critically ill patients.

To be conservative, in our analysis we use the lower costs of survivors rather than mean costs for all BMT patients. To estimate the mean total cost of BMT treatment for survivors, we reduce the mean total cost of $67,772, shown in table 1, by 2.4 percent **($1,627).** Thus, the adjusted total BMT treatment cost for the analysis is $66,145. (Note that this cost refers to the total cost of BMT treatment rather than only the direct treatment costs.)

Cost of Conventional Therapy

A CEA of a policy or procedure must always be performed with respect to an alternative policy or procedure. Often the alternative is stated implicitly, as when a project is compared to no project (e.g., a new bridge v. none at all, or use of a new technology where none had existed before). In the case of treatment for aplastic anemia and leukemia, an interesting dilemma is evident. Conventional therapy for patients with these diseases is always undertaken, despite the fact that such treatment does not significantly improve patient outcome.

If one were to do a CEA of conventional therapy compared to no treatment, the conclusion would be that the substantial expenditure of resources on conventional therapy has little to show in terms of patient outcome. One might argue, therefore, that conventional treatment should be abandoned as being of no benefit. This would then lead one to analyze BMT therapy as an alternative to no treatment at all.

However, the fact is that we do not simply abandon patients who are afflicted by these diseases. When BMT therapy is not feasible, either for lack of a suitable donor or for financial reasons, patients are given conventional treatment, despite the lack of a significantly improved outcome. This being the case (for whatever reason), BMT therapy is an option that represents an alternative to conventional therapy. Therefore, the cost of BMT therapy must be considered not in isolation but as compared

to the cost of conventional therapy. The net, or marginal, costs of BMT therapy are reestablished by subtracting the costs of conventional therapy from those of BMT.

For purposes of our analysis, mean direct costs for conventional treatment were calculated for patients with acute leukemia and aplastic anemia who were eligible for BMT but could not receive this treatment because of an absence of suitable donors. Costs for patients with acute leukemia were analyzed from time of relapse; those for patients with severe aplastic anemia were analyzed from time of diagnosis. These time periods were selected because they coincided with the eligibility requirements for BMT. Indirect costs (lost wages) to patients were not calculated for any of the patient/treatment groups, because all patients were assumed to be too ill to return to work. Conventional treatment does not generate the indirect costs to donor and family that BMT therapy generates.

The mean direct costs of conventional treatment for aplastic anemia and for acute leukemia are shown below.

For aplastic anemia , ... $21,729
For acute leukemia 30,105

Cost= Effectiveness Calculations

We calculate the BMT cost-effectiveness ratios twice, first with "lives saved" **as** the denominator, and then with "years of life extended" as the denominator. Unlike the first calculation, the latter calculation is not straightforward, because the long-term survival rate of BMT patients is not known. We estimate long-term BMT survival most optimistically by using the observed 3-year survival rate to estimate long-term survival, and we calculate years of life extended assuming that the longevity of BMT patients, who survive for 3 years, equals that of the general population. There is no evidence by which we can verify our assumption concerning the longevity of BMT survivors; therefore, we must recognize that by using that assumption we are calculating an upper bound to the benefits of BMT treatment. To show the effects of alternative assumptions, we use a sensitivity analysis. An average life extension of 53 years is assumed to be gained by survivors of BMT treatment (the mean age of BMT patients is 22.2 years) (5). For purposes of a sensitivity analysis, life extensions of 25 and 10 years are assumed.

Discounting of benefits that accrue in the future–whether they be real benefits (e.g., years of life) as in this study, or monetary benefits—is necessary so that benefits in each year can be made comparable, and hence additive. The significance of discounting is that benefits in the future are valued less than those accruing now. This procedure is entirely consistent with the rate of time preference experienced generally, with present wealth more highly valued than deferred wealth.

There is no agreement in the literature as to the appropriate discount rate, but the prevailing, commonly observed rate of interest on loanable funds is often suggested as appropriate. We use 10 percent as the discount rate in our analysis, but also show calculations for 8 and 12 percent to test for sensitivity. Our cost-effectiveness ratios with "lives saved" as the denominator do not employ discounting, because all benefits (lives saved) are assumed to result in the current period, when the costs are incurred. The ratios with "years of life extended" as the denominator do employ discounting, because these benefits (extended years of life) accrue in the future as well as the present.

Even with discounting, one additional caveat must be offered concerning the implication of the results, This concerns the distinction between average and marginal costs. Average costs measure the average expenditure for a given set of patients, as reported above. This is not the appropriate cost estimate, however, if one considers marginal changes in output levels of a program. We do not know, for example, if we were to expand the treatment by, say, 10 patients per year, whether the cost per additional patient would be higher or lower than the average cost per patient. If there are economies of scale, one would expect the marginal costs to be lower than the average. If there are diseconomies of scale, however, the policy-relevant marginal costs would exceed the average.

Cost-Effectiveness Ratios

The net cost of BMT therapy is calculated as the mean cost for BMT therapy minus the mean cost for conventional therapy. Thus, the net cost of BMT therapy for aplastic anemia is $66,146 minus $21,729, or **$44,417;** and the net cost of BMT therapy for acute leukemia is $66,146 minus $30,105, or $36,041.

Cost-effectiveness ratios for BMT are calculated as follows:

For lives saved:

C/E = Net BMT treatment cost/survival rate

Aplastic anemia,

C/E = $44,417/0.42 = $105,755 per life

Acute leukemia,

C/E = $36,041/0.13 = $277,239 per life

For extended years of life (before discounting):

C/E = Net BMT treatment cost/survival rate x 53 years

Aplastic anemia,

C/E = ***$44,417/(0.42) (53) = $1,995*** per year

Acute leukemia,

C/E = $36,041/(0.13) (53) = $5,231 per year

Discounting extended years of life reduces the present value of these benefits, thus raising the cost-effectiveness ratios. Table 2 shows the-benefits for three alternative life extensions (53, 25, and 10 years) and four alternative discount rates (0, 8, 10, and 12 percent). Discounting extended years of life dramatically affects the benefits of a life-extending program. By discounting, 53 extended years of life are valued at only 18 to 25 percent of their undiscounted value. The higher the discount rate, the greater the reduction in value of extended years of life. The impact of discounting is particularly great for the 53-year life extension assumed in our analysis, but is less if the life extension is relatively short (e.g., 10 years).

Table 2.—Present Value of Years of Life Extended
(with different discount rates)

Years of life extended	Discount rate 0%	8%	10%	12%
53	53	13.3	10.9	9.4
25	25	11.7	10.1	8.9
10	10	7.7	7.2	6.7

The results of applying these discount factors to the cost-effectiveness ratios for extended years of life are presented in table 3. Several observations can be made about the calculations of cost per discounted year of life extended. The first is that the results are more sensitive to assumptions regarding life expectancy when the life expectancy is relatively short than when the life expectancy is relatively long. In other words, at any of the discount rates used, the cost per year of life extended is far more sensitive to a difference in the assumed life extension from, say, 10 to 25 years than to a difference between 25 and 53 years, even though the latter span of 28 years is much greater than the former span of 15 years. This **means** that the results of this analysis are not very sensitive to the assumed life extension, as long as the figure is high (e.g., 53 years). However, if the life expectancy figure is low, the results would be sensitive to the exact figure assumed.

Secondly, the choice of discount rate substantially affects the findings. If one alters the assumptions of a 10-percent discount rate by 2 percentage points either way, the cost-effectiveness ratios for a 53-year life extension will vary by approximately 10 to 30 percent. If the life extension is less (e.g., 25 or 10 years), the significance of the choice of discount rate is lessened.

Adjustments for Quality of Life of Survivors

Measures to determine quality of life and health status are still being developed, and little agreement has yet been reached concerning appropriate scaling. In the case of BMT therapy,

Table 3.—BMT Cost per Year of Life Extended
(with different discount rates)

Years of life extended	0%	8%	10%	12%
Aplastic anemia				
53	$ 2,003	$ 7,982	$ 9,740	$11,295
25	4,246	9,074	10,512	11,929
10	10,616	13,788	14,745	15,846
Acute leukemia				
53	$ 5,231	$20,845	$25,435	$29,494
25	11,089	23,696	27,450	31,150
10	27,724	36,005	38,505	41,379

some attempt to employ the concept of quality of life is crucial because of the serious medical condition of many of the patients who survive the treatment. To ignore the question of quality of life because of the seriousness of methodological or measurement difficulties would implicitly assume that all lives saved are equal in value, regardless of the functional state of the survivors. If CEA is to be used to compare programs, failure to measure quality of life is a more serious omission. Therefore, we make a limited, though inherently reasonable, attempt to measure this.

Difficulties associated with measuring quality of life in BMT patients are numerous and significant. Direct interviews with BMT patients treated at UCLA were impossible, since many are no longer alive and over 50 percent of the BMT patients and families do not live in the Los Angeles area where this study was conducted. Review of medical charts was tedious, and the charts proved to be an inadequate source of information regarding the quality of BMT patients' lives posttransplant.

Through discussion with members of the UCLA BMT team, one nurse was identified as a person who had worked closely with all BMT patients and their families during hospitalization and clinic followup visits. The same nurse also maintained contact with all patients by telephone until the patients' death. We interviewed this nurse and asked her to assess quality of life (short- and long-term) for each BMT patient. A simple instrument was developed to provide a subjective measure of quality of life for BMT patients.

All BMT patients treated at UCLA between March 1, 1974, to August 31, 1978, were evaluated. Two rankings were given to each BMT patient who survived more than 1 year following transplantation: 1) a short-term quality score (3 to 12 months posttransplant), and 2) a long-term quality score (from 12 months posttransplant until death or until completion of the data collection on August 31, 1978).

Because of the limitations mentioned previously, it would have been unrealistic to expect one individual to remember specific details about 107 BMT patients. For this reason, a simple "degree of dependence v. independence" measure was used as a proxy measure for quality of life of survivors. The following 4-point scale was developed and used:

O = *Total dependence:* Usually a patient who had developed complications (e.g., GvHD or interstitial pneumonia) which severely limited self-care activities, but did not require hospitalization.

1 = *Partial dependence:* Able to perform self-care activities, but unable to return to school or work, or in the case of young children play with friends.

2 = *Semi-independence:* Able to return to school, work, or play on a part-time basis.

3 = No *limitations:* Able to engage in normal activities, returned to work or school full-time.

Because of the risks associated with the early phase of convalescence,[3] we decided to measure quality of life of survivors only after a BMT patient had been discharged and had been at home for at least 1 month (usually 3 months) subsequent to transplantation.

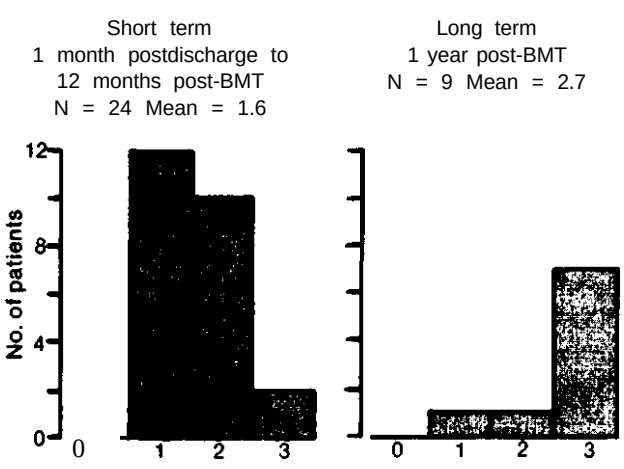
Short- and long-term quality of life for aplastic anemia patients given BMT therapy are displayed in figure 4; short- and long-term quality of life for acute leukemia patients given BMT therapy are shown in figure 5.

It is important to emphasize the obvious limitations of our quality-of-life measure so that the data can be properly interpreted. The limitations are as follows:

- The instrument (4-point ranking scale) was not tested for either reliability or validity.
- Dependence v. independence is only a proxy measure for quality of life.
- The data represent the interpretation and view of one individual (the nurse—not the patient or family) and therefore must be considered very subjective.

[3] If the bone marrow engrafts and the recipient survives the immediate posttransplant period, he or she will be discharged from the hospital, but will remain at risk with regard to the long-term complications of GvHD and interstitial pneumonia (which typically occurs between 1 and 7 months posttransplant).

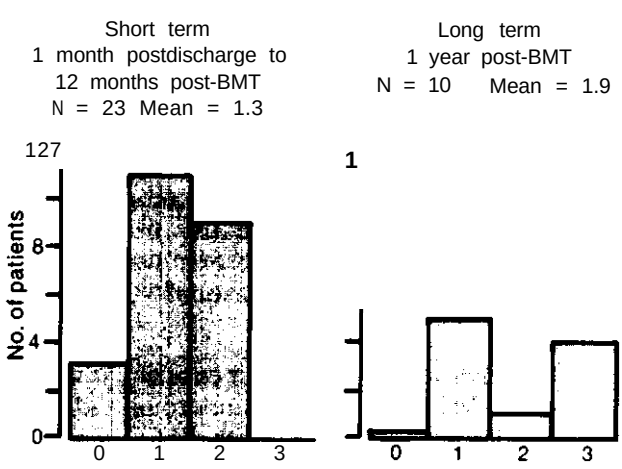
Figure 4.—Quality of Life for Aplastic Anemia Patients Given Bone Marrow Transplant[a]



0 = Total dependence.
1 = Partial dependence (unable to return to work or school).
2 = Partial dependence (able to return to part-time work or school).
3 = No limitations.

[a]Patients treated at UCLA's Bone Marrow Transplantation Program from Mar. 1, 1974, to Aug. 31, 1978.

Figure 5.—Quality of Life for Acute Leukemia Patients Given Bone Marrow Transplant"



0 = Total dependence.
1 = Partial dependence (unable to return to work or school).
2 = Partial dependence (able to return to part-time work or school).
3 = No limitations.

[a]Patients treated at UCLA's Bone Marrow Transplantation Program from Mar. 1 1974, to Aug. 31, 1978.

- The sample size was extremely small:
  Aplastic anemia: N = **24**
  Acute leukemia: N = 23

Analysis of the data with these limitations in mind shows that the mean short-term quality of life for 24 patients with aplastic anemia is 1.6 and is slightly lower, 1.3, for 23 patients with acute leukemia. Less than half the patients in either group survived 1 year posttransplant, so the sample for long-term quality of life is very small. The mean long-term quality of life for 9 patients with aplastic anemia is 2.7 and for **10** patients with acute leukemia is 1.9.

Cost-effectiveness ratios are adjusted for quality of life only for long-term survival. The quality adjustment factors (Q) are calculated as follows.

Q = observed quality / potential quality of life
Aplastic anemia, Q = (2.7) / (3.0) = 0.90
Acute leukemia, Q = (1.9) / (3.0)= 0.63

Applying this quality adjustment to the BMT cost-per-life-saved calculations yields the following ratios.

For lives saved:

C/E = Net BMT treatment cost / survival rate **x** *Q*
Aplastic anemia,
C/E = $44,417 / (0.42) (0.90)= $117,505 per life saved
Acute leukemia,
C/E = $36,041 / (0.13) (0.63)= $440,061 per life saved

Applying the quality adjustment to the BMT cost-effectiveness ratios for extended years of life in table 3 yields the results presented in table 4.

Table 4.—BMT Cost-Effectiveness Ratios[a] With Quality. of-Life Adjustment

Years of life extended	00/0	*80/0*	*100/0*	*12%*
Aplastic anemia				
53	**$ 2,327**	**$ 9,307**	$11,308	$13,122
25, ...	4,933	10,556	12,233	13,850
10	12,331	16,031	17,262	18,496
Acute leukemia				
53	**$ 8,303**	**$33,213**	**$40,352**	**$46,830**
25	**17,603**	**37,669**	**43,654**	**49,463**
10	44,006	57,209	61,609	66,010

[a]See table 3

BMT COST IN PERSPECTIVE

A review of the literature shows a surprising degree of variation in the cost effectiveness of lifesaving procedures. This variation is difficult to justify on the basis of economic efficiency. Unequal cost-effectiveness ratios for various programs, at least at the margin, imply that additional lives or years of life could be saved by reallocating resources among programs. As a few examples will illustrate, however, the criterion of equal marginal cost effectiveness of alternative programs is rarely applied in practice. Neuhauser (6) **estimates** that elective inguinal herniorrhaphy costs approximately $120,000 per life saved. Barnes (1) estimates that treatment for end-stage renal disease costs from $22,000 to $27,000 per life saved if a kidney transplant is employed, assuming a 5-year survival period. Benedixen (2), who studied the costs per year of life saved by intensive care treatment, found the figures to range from $84 for treatment for an overdose of barbiturate to $180,000 for hepto-renal failure.

A large part of the BMT patient population is young. Therefore, the high cost of BMT treatment is amortized over a far longer period than are the costs of some other life-extending programs that affect an older population (e.g., cardiac care or other cancer treatments). Chronic dialysis for end-stage renal disease costs an estimated $6,000 to $30,000 per year of life extended (1). Coronary artery bypass surgery, though apparently not lifesaving, may improve the quality of remaining years of life. Weinstein, et al. (10) estimate the cost of such surgery to be from $25,000 to $53,000 per quality-adjusted year of life. Multiple trauma treatment costs just over $6,000 per year of life extended (2).

With adjustments for quality of life, the cost effectiveness of BMT therapy is worsened, especially for one of the target populations—patients suffering from acute leukemia. For aplastic anemia patients who undergo BMT therapy, the adjustment factor is close to 1.0, so adjustment for quality of life only slightly worsens the cost-effectiveness ratios. Acute leukemia patients who undergo BMT therapy have a worse short- and long-term outcome, so the adjustment for quality of life more adversely affects the cost-effectiveness ratios.

POLICY IMPLICATIONS

The significance of this case stud, for policy analysis extends in two directions. First, the study highlights several complexities associated with performing CEAS, including the effort to take into account quality of life. One finds that BMT therapy has substantially different costs per life saved or year of life extended when it is applied to different patient populations (i. e., aplastic anemia v. acute leukemia). Thus, generalizations about a procedure for all patients are not always appropriate. One also observes the importance of selecting an appropriate alternative procedure to the one being analyzed. In the case of BMT, conventional treatment is the existing alternative notwithstanding its limited efficacy.

The study also suggests a new approach to controlling the process of technological diffusion. Under conditions of scarce resources, allocation decisions must be made which, by definition, will deny life to some while extending it for others. Third-party intermediaries, both public and private, might well consider this issue in deciding which services to cover and for whom, as they act as "agents" for large numbers of patients, or in the case of public agencies, for society at large. Failure to consider it tacitly assumes no resource scarcity—an assumption that will continue to drive health care expenditures up at an unmoderated rate, as the most expensive therapy is provided for all in need,

Third-party payers commonly reimburse for any service that is deemed "medically necessary, " the judgment of which is generally left to the physician in charge. However, a more con-

servative approach, incorporating some of this judgment into the insurer's own policy process, is equally feasible. In the case of a new technology, the policy options for third-party payers are more numerous than they are in the case of procedures that have already been widely diffused and employed. The major difference is that in the case of a new technology such as BMT, a third-party intermediary maybe able to specify the sites at which the procedure will be reimbursed, as well as patient characteristics of those entitled to coverage. In the case of BMT, six centers currently perform the procedure on a significant scale; given its high degree of complexity and reliance on various subsystems (tissue-typing, laboratory, radiology, etc.), one might wish to discourage this technology's widespread diffusion, while at the same time accepting current or somewhat altered treatment levels.

Another role for third parties in the case of a new technology is to define a procedure as either "treatment" or "research' '-depending on either its success or cost (or a combination of the two) —with the implication that "research" should be supported in demonstration-type settings, on limited numbers of patients, and from a totally separate budget from the budget for "treatment" (which, morally, might be offered to all in need). One would define a procedure as being treatment rather than research as soon as its efficacy or costs (or both) approached some frequently observed level. Little of this sort of policy analysis is currently being done. The degree of freedom open to the third parties is far greater than typically practiced, and more judicious use of the reimbursement instrument would certainly have an enormous impact on the diffusion and distribution of new technology.

One last caveat is in order as one translates a CEA into the language of policy. Analyzing a new medical procedure is inherently difficult because the data tend to be obsolete as soon as the procedure is analyzed. New developments occur rapidly. With regard to BMT, for example, altered protocols appear to be leading to improved results, though more recent data do not lead themselves to long-term extrapolation.

For these reasons, a CEA of a particular technology is somewhat like a single brick, which, no matter how well made, cannot provide shelter. A single piece of analysis cannot indicate how resources might be allocated until it is put beside other pieces, Only after many comparable studies are analyzed can one see where limited resources might best be put. Our CEA of BMT therapy, therefore, is little more now than a single element in the entire technology assessment picture.

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APPENDIX: MEAN HOSPITAL COSTS AND PROFESSIONAL FEES FOR PATIENTS AND DONORS IN UCLA'S BONE MARROW TRANSPLANTATION PROGRAM

Table A-1 .—Mean Expected Charges for Hospital Costs[a] for a Hospital Stay of a UCLA BMT Patient[b]

1. Room and nursing care[c]	$18,232.20
2. Operating and special procedure rooms	4,195.20
3. Emergency service	7.70
4. Anesthesia	40.00
5. Medical and surgical supplies	2,269.94
6. Inhalation therapy	278.38
7. Inhalation therapy IPPB	70.00
8. Pharmacy: a. Medications	6,043.54
b. IV solutions	1,209.35
c. Take-home drugs	671.51
9. Blood bank	4,129.30
10. Radiology: a. X-ray	1,042.50
b. Isotopes or therapy	1,074.10
11. Laboratories: a. Outside	321.37
b. Blood gases	215.70
c. Clinical	19,722.47
12. Pathology	118.70
13. Outpatient services	121.10
14. Physical and occupational therapy	329.17
15. Maxillo-facial prosthetics	329.17
16. Special private duty RNs	304.00
17. Echogram	22.00
Total	$60,743.43

[a]Tabulated charges are not actual charges, but represent the product of the actual charge for a service and the probability of that service's use

[b]Patients treated at UCLA's Bone Marrow Transplantation Program from Mar 1, 1974, to Aug., 31, 1978.

[c]The average hospital stay for all BMT patients is 72.1 days.

SOURCE: Calculations based on data from UCLA's Bone Marrow Transplantation Program, Los Angeles, Calif

Table A.2.—Mean Expected Charges for Professional Fees[a] for a Hospital Stay of a UCLA BMT Patient[b]

1. Office examination—extended	$ 132.00
2. Office examination—hematology	19.50
3. Initial hospital examination	49.50
4. Hospital reexamination	240,00
5. Initial hospital visits	375.00
6. Hospital visits	1,678.50
7. Physical—complete	12.50
8 Consult—cardiology	46.50
9 Consult—comprehensive	46.50
10 Consult—dermatology	10.00
11 Consult—hematology	25.00
12 Consult—infectious disease,	42.00
13. Consult—liver	12.00
14, Consult—respiratory	24.00
15. Bone marrow tray	1.90
16. Bone marrow	2.50
17. Bone marrow aspiration	20.00
18. Spinal puncture tray	1.90
19. Scalp-vein	0.45
20. Chemotherapy—parental	4.00
21. Esophagastroduodenopsy	20.00
22. Pericardiocentesis	10.00
23. Fiberoptic bronchoscopy	71.00
24 Biopsies	10.00
25. Echocardiogram	46.40
26. Medical report	0.60
Total	$2,880.25

[a]Tabulated charges are not actual charges, but represent the product of the actual charge for a service and the probability of that service's use.

[b]Patients treated at UCLA's Bone Marrow Transplantation Program from Mar. 1, 1974, to Aug. 31, 1978.

SOURCE: Calculations based on data from UCLA's Bone Marrow Transplantation Program, Los Angeles, Calif.

Table A3.—Mean Expected Charges for Hospital Costs and Professional Fees[a] for a UCLA BMT Donor

Hospital costs	
1. Room and nursing care	$ 288.00
2. Operating and special procedure rooms	239.00
3. Anesthesia	226.00
4. Medical and surgical supplies	13.50
5. Pharmacy a. Medications	7.70
b. Intravenous solutions	24.00
6. EKG, EEG, EMG service	26.00
7. Outside laboratories	27.00
8. Clinical laboratories	333.00
Total	$1,184.20
Professional fees	
The only professional fee is that for a bone marrow aspiration, totaling $1,000.00.	

[a]Tabulated charges are not actual charges, but represent the product of the actual charge for a service and the probability of that service's use.

SOURCE: Calculations based on data from UCLA's Bone Marrow Transplantation Program, Los Angeles, Calif

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