2）臨床特性との関係

PCI症例のうち急性心筋梗塞症例の占める比率は予想通り年々増加傾向にあった。一方PCI症例のうち１枝治療を行ったものと多枝治療を行ったものの比率を見ると、94年当時では多枝病変の治療にやや積極的であったものの、その後主に１枝病変を中心的に治療する傾向に落ち着いていた。

表４：PCI施行件数　診断別

year	non-AMI	AMI	Total
94	342 89.76	39 10.24	381 100.00
95	353 85.89	58 14.11	411 100.00
96	356 84.56	65 15.44	421 100.00
97	417 84.58	76 15.42	493 100.00
98	405 76.56	124 23.44	529 100.00
Total	1873 83.80	362 16.20	2235 100.00

表５：PCI施行件数　治療枝数別

year	1枝	2枝	3枝以上	Total
94	281 73.95	80 21.05	19 5.00	380 100.00
95	369 89.78	38 9.25	4 0.97	411 100.00
96	377 90.84	37 8.92	1 0.24	415 100.00
97	421 88.45	53 11.13	2 0.42	476 100.00
98	472 91.65	41 7.96	2 0.39	515 100.00
Total	1920 87.39	249 11.33	28 1.27	2197 100.00

一方CABGは３枝バイパスが主体であり、その傾向には年次で大きな変化は見られなかった。

表６：CABG施行件数　バイパス枝数別

year	１枝	２枝	３枝	Total
94	16 12.90	44 35.48	64 51.61	124 100.00
95	16 12.12	40 30.30	76 57.58	132 100.00
96	11 7.59	54 37.24	80 55.17	145 100.00
97	16 10.19	32 20.38	109 69.43	157 100.00
98	26 15.20	56 32.75	89 52.05	171 100.00
Total	85 11.66	226 31.00	418 57.34	729 100.00

男女別・年齢層別（６５歳未満・以上）で分けてみてもPCI/CABGともに上記傾向に大きな違いは見られなかった。

３）New Device、特にStentの使用頻度の年次変化

予想通り、９６年以降PCIを行った症例のうち、Stentを用いたものの比率が上昇しはじめ、９８年ではStent使用率が５０％を越す勢いに至っていた。

表７　Stentの使用頻度の年次推移

year	Stentなし	あり	Total
94	220 88.00	30 12.00	250 100.00
95	354 88.94	44 11.06	398 100.00
96	329 78.90	88 21.10	417 100.00
97	331 67.14	162 32.86	493 100.00
98	258 48.77	271 51.23	529 100.00
Total	1492 71.49	595 28.51	2087 100.00

これを診断別に見ると、非急性心筋梗塞症例・急性心筋梗塞例いずれでも年次的にStentの使用率が増加してきており、その比率の推移に診断別の違いは見られなかったが、急性心筋梗塞に対するPCI施行例数が急速に伸びているため実数でみると急性心筋梗塞に対するStent使用率の伸びが著しく目立つ。

表８；Stent 使用頻度の年次推移　急性心筋梗塞例のみ

year	Stent なし	あり	Total
94	23 88.46	3 11.54	26 100.00
95	53 94.64	3 5.36	56 100.00
96	50 78.12	14 21.88	64 100.00
97	50 65.79	26 34.21	76 100.00
98	58 46.77	66 53.23	124 100.00
Total	234 67.63	112 32.37	346 100.00

これを裏付けるように、PCI 実施が待機的であったか緊急的であったかに分けてみると待機的 PCI はほぼ３５０症例前後で推移していたのに対し、緊急的に実施された PCI の数が年次的に増加していることがうかがわれる。緊急症例の多くは急性心筋梗塞ないし不安定狭心症などの急性冠症候群症例であると考えられることから、こうした患者層に対してより積極的に PCI が実施されるようになってきたことが PCI 症例数の増加の強い要因になっていると見て取れる。そうした傾向の背景に Stent の普及やその適応対象の拡大が関与した可能性が強いと考えられる。

表９；待機的・緊急的 PCI の実施状況

year	緊急 PCI	待機的 PCI	Total
94	57	324	381
95	68	343	411
96	74	344	418
97	116	364	480
98	152	362	514
Total	467	1737	2204

４）予後の推移

初回 PCI を行った１３３６例について術中・術後合併症を集計した。Major な合併症として術死亡、術後心筋梗塞、ならびに 24 時間以内の緊急 CABG を総計した。下表に示すとおり、合併症発生率に目立った年次傾向は認められなかった。

表10　初回PCI症例の合併症発生率　年次集計

year	合併症なし	あり	Total
94	213 95.95	9 4.05	222 100.00
95	226 97.84	5 2.16	231 100.00
96	225 97.40	6 2.60	231 100.00
97	309 99.68	1 0.32	310 100.00
98	334 97.66	8 2.34	342 100.00
Total	1307 97.83	29 2.17	1336 100.00

急性心筋梗塞や高齢者などハイリスク群が相対的に増えてきていることを考えると、率に変化が見られないことは合併症発生が相対的に減少しているとも取れる。実際非心筋梗塞例での合併症発生率は１－３％で推移していたが、急性心筋梗塞症例に絞ってみると94-95年では７－８％であったものが、96年以降２－４％に低下していた。一方年齢別では65歳未満症例で94-95年当時３－４％見られていた合併症が97-98年ではほぼ０％となっていた。65歳以上症例では年次による変動が大きくはっきりとした傾向はつかみにくいが、むしろ98年で最も高い合併症発生（7/175例＝４％）が見られている。なおCABGについては同様の情報が抽出できていないため今回は検討を見送っている。
次に初回PCIを行った1336例について、術後1年以内の予後ならびにCross-over（PCI症例がCABGに移行、ないしその逆）の状況を集計した。

表１１；初回PCI症例の術後1年以内の死亡率(%)診断別

year	非心筋梗塞例 (813 obs)	心筋梗塞例 (295 obs)
94	8.54	0.00
95	2.05	8.16
96	4.96	1.59
97	0.57	2.99
98	0.00	1.41
Total	3.08	2.71

表１２；初回 PCI 症例の術後１年以内の死亡率（%）年齢層別

year	65 歳未満	65 歳以上
94	1.45	16.90
95	2.73	4.71
96	1.74	6.74
97	1.49	0.93
98	0.00	0.83
Total	1.42	5.07

非心筋梗塞例ならびに 65 歳以上の症例で 97 年以降に死亡率の著しい低下を認めていた。
CABG 症例については予後情報の欠損が多く認められていたため今回は集計を控えた。引き続き追加データの整備を進め追加検討を行う予定である。
最後に術後 1 年以内の入院日数（総計）を集計した。

表１３；初回 PCI 症例の術後１年以内の総入院日数（中央値　IQR）　診断別

year	非心筋梗塞例 (696 obs)	心筋梗塞例 (298 obs)
94	32(15-51)	42(32-54)
95	33(17-54)	44(33-67)
96	27(13-55)	43(32-56)
97	20(10-37)	38(29-47)
98	27(12-43)	31(23-41)

表１４；初回 PCI 症例の術後１年以内の総入院日数（中央値　IQR）　年齢層別

year	65 歳未満 (567 obs)	65 歳以上 (427 obs)
94	32(14-47)	40(23-54)
95	39(29-58)	40(21-65)
96	35(15-50)	39(16-62)
97	28(11-41)	26(12-43)
98	30(13-39)	29(14-46)

いずれの層でも経時的に入院日数の減少が見られているが、ことに心筋梗塞症例と 65 歳以上症例においてその傾向が強く認められる。

考察

以上の分析からほぼ仮説の裏付けを取ることができた。94-95年と比較し96-98年において Stent の使用率が急上昇し、その傾向や比率は米国側データと比較してほぼ同等であり、Stent 技術が日米でほぼ同時進行的に普及・適応拡大が見られたことがうかがわれる。またこれと時期を一にして、合併症率の低下、死亡率の減少が見られており、大枠でこれもまた日米で同様の傾向を認めるに至った。死亡率や合併症率の絶対値については米国の其れに比して日本の数値は一貫して低い値が見られているが、患者の臨床像が比較できない以上単純に比較することは危険である。これまでも米国に比して日本の臨床現場では比較的軽症の患者もインターベンションの対象とされることが指摘されている。従って死亡率や合併症発生率が日本で低いのは単に患者ミックスが軽症症例も含んでいるためかもしれない。今後日米双方で比較可能なレベルの臨床データを入手した上でさらに検討をする必要がある。

在院日数については米国のそれと日本のそれでは絶対値が大きく異なるが、在院日数が94-95年と96-98年で減少傾向にある点では同様であった。米国ではすでに94年段階で Managed Care 保険による Utilization Control がその極に至っていたこと、むしろ97年あたりを境にいわゆる HMO 批判がはじまり入院日数規制がやや弱まってきたことなどが、減少傾向が著しくなかった理由のひとつとも考えられる。一方日本においては米国ほどの急速なものではないが90年代を通じて在院日数の削減を目指したプロセスイノベーションに関心が持たれるようになったことから緩慢ではあるものの低下傾向につながったものと考えられる。

最後に本邦の分析では年齢層別・診断別に Stent 技術普及の程度、アウトカム、在院日数の変化に違いが見られることが指摘された。すなわち仮説どおり高齢者・心筋梗塞症例などにおいて PCI がより積極的に用いられており、その背景に Stent を始めとする新しいより効果的な技術の導入と、その適応をめぐる補助診断や補助治療の向上などが関与していたであろうと推測される。またこうしたハイリスク群においてもアウトカムの改善や在院日数の削減などが観察された。

Stent は POBA に比べて高額な治療器材であるが、一方で臨床的な効果性、特に再狭窄率の低下による再 PCI 治療を削減することによるコスト削減の分で、費用効果性に優れるとする見方もある。しかし、これまでの欧米の諸研究では出血事故が多かった分で費用効果増分が相殺されてしまうとする報告も見られた。しかし、そうした研究結果は95年以前の診療・治療判断のもとで行われたものであり、96年以降に大きく変化した診療・治療判断のもとで再度 Stent をはじめとする新技術の評価がなされる必要がある。今回 Primitive ではあるが、Stent 普及と時期を一にして治療効果や質に影響すると思われる諸指標の改善傾向が日米両国の high volume institutes において観察されたことから、今後 Charge データとあわせた費用効果性に関する分析を進める意義を認めることができた。

結論

米国大学関連病院と本邦のセンター病院の 2 施設から得たデータをもとに、90 年代に劇的な変化を遂げた虚血性心疾患治療のプラクティスパターンとアウトカムの変化を記述的に検討した。当初予想通り、日米においてほぼ同時期に新技術の普及ならびにアウトカム上の変化傾向が見て取れた。今後費用効果に関する検討を進め、技術導入の及ぼす医療経済的影響について分析を進める意義が認められた。

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「社会保障の改革動向に関する国際共同研究」
共同研究２：「病院サービスの高度化とその経済効率性に関する実証分析」

Preliminary Report for the NCCH-Stanford Collaborative Study*

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Introduction

To provide explicit evidence on the nature and magnitude of technological change in the U.S. health care system, as well as to explore why these changes have occurred, we analyze recent changes in treatment trends for AMI in the United States and for patients with ischemic heart disease (IHD) admitted for CAG, PCI, or CABG procedures in a major teaching hospital with advanced cardiovascular capabilities. In the future, we are willing to extend the United States analysis to procedure trends for patients admitted to the hospital with diagnoses of IHD so that the overall US cohort and hospital cohort will be comparable. However, in this current report on US procedure trends, we will concentrate on trends for AMI patients.

In Section I of this report, we use detailed micro-data to describe the changes in AMI treatment that have occurred in recent years. The treatments used in AMI care are largely the same as those used in IHD care, so, with the exception of the specific trend estimates, the information contained in this section may be generalized to IHD care. Many cardiac treatments have changed, and summarizing the causes as well as the consequences of these changes is

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necessarily speculative. Nonetheless, the results presented here suggest that technological change in the United States has differed in important respects from changes in other developed countries.

In Section II, we describe the future comparison we plan to undertake looking at the United States nationwide trends for major cardiac procedures compared to the same procedures in a major U.S. research hospital. We expect to find a pattern of early adoption of high-tech procedures and higher trends than the national average in the hospital. By comparing to the national average, we will be able to determine whether the U.S. teaching hospital of interest in this study is indeed at the vanguard of technology diffusion in the U.S. as we have hypothesized. If the teaching hospital under scrutiny does appear to have a higher procedure rate than the national trend, it will then be interesting to compare high-tech care in the U.S. and Japan.

**In the future, comparisons of the high tech trends in the U.S. to those in Japan, including trends in a major teaching hospital in each country, may provide important insights about the costs, benefits, and productivity consequences of differences in incentives for technological change in alternative health care systems.

Section I. Procedure Utilization Trends in the United States

We present evidence on procedure utilization trends by analyzing large administrative databases to describe changes in some key "high-tech" AMI treatments. By high-tech treatment, we mean the use of procedures and devices that require substantial fixed investments in equipment and specialized personnel, or that have high equipment and personnel costs with each use, or both. We use administrative records from the Medicare program to describe trends in high-tech procedure use for the entire U.S. elderly population with AMI for 1985-1997, and we use hospital records from the state of California to describe trends in high-tech procedure use for the nonelderly population of the state for 1991-1996. Reliable longitudinal data on large populations of nonelderly AMI patients is not available prior to 1991; for the 1980s, we review some relevant clinical studies to supplement our results for the elderly.

The summary of changes in AMI treatment to be discussed shortly will focus on changes in treatment rates. New clinical trials, increased clinical experience, or other new information to guide practices may also improve the ability of health care providers to time the allocation of treatments more effectively, or target their use to patients who are particularly likely to benefit. Unfortunately, little longitudinal evidence on such criteria or "appropriateness of care" issues is available in the United States, for several major reasons. First, few large studies of U.S. AMI populations collected detailed information on patient characteristics and treatment prior to the 1990s. Second, the criteria for care depend on many complex patient factors that may be difficult to capture for analytic study, even with detailed record reviews. Thus it may be possible to identify some patients who clearly would not benefit from certain treatments, but it is hard to capture all of the subtleties of cases that may influence physician decisions.

In recent years, more studies of appropriateness of care have been published. In general, these studies do not find much evidence of clearly inappropriate use of high- or low-tech treatments in AMI care. However, most of these studies classify large shares of patients in "equivocal" or "possibly appropriate" categories, where the benefits of the treatment are unknown or likely to be modest. Substantial variations in treatment rates, especially for intensive cardiac procedures, continue to exist not only across hospitals but also across small geographic areas in the United States. These variations do not appear to be diminishing, though few studies of changes in practice variations over time have been published. A final type of evidence suggesting that experience effects are important is the fact that larger hospitals have significantly lower mortality rates in AMI care (e.g., Luft et al., 1990), and that the benefits of treatment at a large hospital have increased over time (McClellan and Noguchi, 1998). But few studies have attempted to trace volume effects to differences in particular treatment choices. For all of these reasons, it is very difficult to quantify how the appropriateness of AMI treatment *given* rates of treatment use in the United States has changed over time. Nonetheless, trends in the appropriateness or experience of care may represent a very important source of outcome improvements.

Another factor to bear in mind is that the characteristics of AMI patients may have changed over time. The demographic characteristics of AMI patients have shifted gradually, toward a slightly older and more female population. Heidenreich and McClellan (1998) conclude that, over the past decade, AMI patients in the United States appear to have slightly higher rates of serious comorbid diseases on admission, and also slightly higher rates of shock. However, a larger share of patients have non-Q-wave infarctions and infarctions in territories other than the left anterior descending artery. Both of these case characteristics are associated with a better prognosis. These trends toward less severe cases might be expected to lead to some improvements in health outcomes and perhaps reductions in costs for AMI care. But it is also possible that the improvements in case characteristics are the result of treatment innovations (e.g., better revascularization treatment leads to lower rates of Q-wave infarcts). Thus, it does not appear that changes in AMI patient characteristics unrelated to heart attack treatment can account for much of the changes in health outcomes and expenditures.

In the current report, we concentrate on treatment changes during the acute "episode" of AMI care. This clinical episode might reasonably be defined to include the 30- or 90-day period following AMI. As the following results show, however, the most dramatic changes in AMI treatment in the United States have occurred in the initial hours and days after the heart attack occurs. In addition to these acute treatments, we also briefly consider changes in treatments designed to prevent first AMIs, post-acute treatments designed to prevent further complications of ischemic heart disease, and the post-acute treatment of AMI complications. We expect that these trends can be generalized to IHD and plan to carry out this analysis in our further work for this project.

In the United States, treatment for AMI and ischemic heart disease has relied heavily on the "open artery" principle, the straightforward idea that reducing or eliminating blockages in coronary blood vessels supplying the heart will prevent heart damage and complications (e.g., Braunwald, 1996). The gold-standard invasive procedure used to assess artery status is cardiac catheterization, which may be followed by either coronary artery bypass graft surgery (CABG) or percutaneous transluminal coronary angioplasty (PTCA) to bypass or remove areas of blockage detected on catheterization.

Figure 1 shows the rapid growth from 1985 to 1997 in the use of these intensive cardiac procedures within 90 days after AMI in elderly AMI patients in the United States.[1] Less than 15 percent of elderly AMI patients underwent catheterization in 1985, compared with more than 50 percent 12 years later. Bypass surgery rates have more than tripled, from less than 5 percent to over 15 percent. Angioplasty growth has been even more substantial, from virtually no use in 1985 to more than 23 percent of patients in 1997. Figure 2 shows the corresponding trends for nonelderly residents of California for 1991-1996.[2] Figure 2 shows that absolute rates of procedure growth are quite similar to those for the overall U.S. elderly population, though the rates of procedure use in any given year are much higher in the nonelderly.[3]

Thus, in recent years, intensive treatment rates have increased at comparably rapid rates in both the elderly and nonelderly. Figure 3 shows that, in recent years, procedure use has increased rapidly even in the older elderly. The Figure shows two broad phases of procedure growth in the elderly. Prior to 1989, although rates were increasing for all demographic groups, they increased relatively more rapidly for the younger elderly (65-69) than for the older elderly (80-89). Since 1989, the absolute rates of procedure growth have been more similar, as procedure growth in the young elderly (already at a high level by 1988) has slowed and procedure growth in the older elderly increased. Increased use of intensive treatments in the older elderly has thus become an increasingly important component of technological change in AMI care in the United States.

Figure 4 shows trends in the use of primary angioplasty, defined as angioplasty within one day of AMI. Though most angioplasty and bypass surgery procedures are performed with the goal of secondary prevention after the patient has been stabilized, typically days to weeks after the initial AMI, primary angioplasty is a method for restoring blood flow to the affected area of the heart *during* an AMI. The goal is to prevent much of the damage associated with the AMI, by preventing the death of the heart muscle affected by the heart attack. The Figure shows that the use of this procedure has been increasing rapidly in the United States in the 1990s. This age gradient in treatment growth contrasts with the trends just described; it is consistent with "new" technologies growing most rapidly initially among younger patients, who generally have fewer comorbidities and complicating conditions.

A related new technology that may be contributing to the rapid recent growth of angioplasty use is intracoronary stents, wire rims that are designed to help keep a blood vessel open after angioplasty. Unfortunately, as with many new technologies, hospital reporting of stent use appears to become reliable in US data only around 1996, several years after the technology was first introduced. Though lacking in years, Figure 5 gives a rough idea of the trends for the elderly and nonelderly, which follow the same patterns as other treatments: the nonelderly gaining access to stents much more rapidly than the elderly. However, a large number of clinical studies (e.g., Bittl, 1996) indicate that stent use has grown even more rapidly than angioplasty use since 1993. Informal interviews with leading US cardiologists suggest that the majority of angioplasty procedures in 1997 probably were done with stents.

Performing angioplasty requires the capability to perform catheterization and revascularization on site. Patients initially admitted to hospitals that do not perform catheterization or revascularization may nonetheless undergo the procedure after transfer. Considerable evidence suggests that when hospitals acquire these technologies, their practices for AMI management become considerably more intensive (McClellan et al., 1994; McClellan and Newhouse, 1997; Cutler and McClellan, 1998). Thus the rapid growth in the use of these cardiac procedures in the United States is a reflection of the substantial growth in the number of U.S. hospitals with catheterization and revascularization capabilities. Figure 6 shows this substantial diffusion of cardiac procedure capabilities to US hospitals over the past decade. The figure shows the proportion of elderly AMI patients who have their first AMI admission at a hospital that is able to perform catheterization, angioplasty, and bypass surgery respectively. A small component (1 to 2 percent) of the increasing admission rates at hospitals with procedure capabilities is due to greater patient selection of larger, high-volume hospitals that acquired these capabilities very early. But virtually all of the increase shown in Figure 6 is the result of more hospitals investing in the capability of performing these procedures.

Hospital use by AMI patients has not fallen much since 1985 in the United States, in contrast to other countries. The average number of hospital days in the year after AMI declined slightly in the early years following implementation of the DRG system, and has not changed much in more recent years. However, this relatively flat total hospital use reflects a more complex pattern: hospital days in the acute period of AMI treatment (within 30 days) have increased slightly, and hospital days spent in later readmissions have decreased slightly. The former trend appears to be the result of more use of the intensive cardiac procedures soon after AMI. The latter trend appears to reflect the fact that cardiac complications have not increased (see below), and that the length of stay for such readmissions with complications have declined.

Trends in the use of coronary and intensive care units in AMI care have been quite similar to the trends in use of overall hospital days. That is, their use in acute treatment has increased slightly, but later readmissions to CCUs have declined slightly. There is little evidence that diagnostic intensive care unit technologies such as Swan-Ganz catheterization or therapeutic intensive care unit technologies such as intubation for respiratory support have increased over time. However, the use of intraaortic balloon pumps has risen, though these devices are used in only a small share of AMI patients. Thus, the increasing intensity of AMI treatment has not translated into much change in the total amount of time patients are spending in the hospital, and it has consisted primarily of increased use of procedures to monitor and restore blood flow to the heart.

Section II. Comparison of Procedure Utilization Trends Nationwide and in a Major U.S. Teaching Hospital

The purpose of this study is ultimately to compare two premier high-tech teaching hospitals, one in the U.S. and one in Japan. Before undertaking such a comparison, we want to ensure that the U.S. hospital chosen for this study exhibits several of the characteristics commonly associated with a high-tech institution: high rates of procedure utilization, early treatment adoption rates and better clinical outcomes. To do this, we will compare data from the teaching hospital with data from all U.S. hospitals. In addition, we will identify differences in the patient characteristics of the teaching hospital versus the overall U.S. population that might influence the procedure trends.

Data and Methodology

The data we are using for this report are derived from Medicare records, including the Medicare Provider Analysis and Review (MEDPAR) files for information on inpatient hospital care, the Outpatient Standard Analytic File for information on outpatient care, and HISKEW and Denominator records for information on patient demographic characteristics (age, gender) and date of death. With these files we were able to recreate the stays of all US patients over the age of 65 from 1994 through 1998. The data for a leading US teaching hospital were also extracted from the Medicare data. In the Medicare dataset, there is a variable for hospitals that lists the identification number for the hospitals to which a patient is admitted. Using this hospital identification number, we were able to identify all patients who were admitted to the teaching hospital for care from 1994 to 1998.

Within each dataset, we selected all patients with a primary diagnosis of Ischemic Heart Disease (IHD) using the International Classification of Diseases 9^{th} revision - Clinical Modification codes of 410 to 414. According to the protocol used in this study, we constructed three procedure based cohorts: 1) patients who underwent coronary angiography (CAG), 2) patients who received percutaneous intervention (PCI) following CAG, and 3) patients who received coronary artery bypass graft (CABG) surgery following CAG.

The size of the patient group who received CABG following CAG in the teaching hospital was problematic. Bypass surgery is typically performed less frequently than either angioplasty (PCI) or angiography (CAG). While this is not a problem at the national level, the small number of patients undergoing CABG after CAG at one hospital may cause sampling errors. In our single hospital sample, the number of patients who receive CABG after CAG range from 80 in 1994 to 57 in 1998, making our results susceptible to the effects of outliers and natural fluctuations in the patient cohort from year to year. For example, in-hospital mortality rates for IHD patients who receive CABG following CAG range from 15% in 1994 to 1.92% in 1996, while the U.S. in-hospital mortality rate is 5.34% in 1994 and 4.91% in 1998. For this reason, we will not use this data to draw conclusions about CABG trends in research hospitals in general and this hospital in particular.

Using the procedure-based cohorts, we calculated simple unadjusted means of the patient characteristics (age, gender, co-morbidities and disease severity), procedure rates (CAG, CABG, and PCI) and outcome rates (length of stay, hospital readmissions, and mortality). Our findings from this preliminary analysis are described below.

Results

Major teaching and research hospitals often service patients who cannot be treated by smaller, less well-equipped hospitals. Often, these larger hospitals serve as regional hubs that dispense care for certain pre-specified conditions because of their state-of-the-art facilities and specialists who perform these conditions. Because of this process of sorting patients by severity, we would expect to find that patients admitted to the teaching facility in this study to be less healthy than the national average and to exhibit more co-morbid conditions, to be older than the average and to have more severe diagnoses.

In order to determine whether sicker patients are transferred to the teaching hospital for cardiac care from the surrounding regions, we would need to compare the hospital's patient characteristics to the to a similar cohort created at the regional level. Undertaking a comparison of patient characteristics between one hospital and the national average is not helpful unless we can assume that the underlying populations are similar. As illustrated in Table 1, the cohorts from the teaching hospital tended to be older, have a larger percentage of men and be slightly less racially diverse, although this could be an artifact of the way Medicare reports race. Medicare records a patient's race as either black or non-black, combining Latinos/Hispanics, Asians and Caucasians into the "non-black" label.

In Table 2, IHD patients from the teaching hospital and in the U.S. exhibited similar rates of co-morbidities: the U.S. average of patients with co-morbidities of diabetes and chronic obstructive pulmonary disease (COPD) is slightly higher than the rates of these co-morbidities for the teaching hospital and patients in the teaching hospital had slightly higher rates of hypertension and peripheral vascular disease. As we can see in Table 1, patients in the U.S. cohort were more likely to have diseased vessels than patients at the teaching hospital. Interestingly, patients at the teaching hospital had higher rates of prior PCI and CABG, although since we did not investigate where patients received these procedures, we cannot use this information as an indication of higher procedure use at the teaching hospital. These general trends in patient characteristics are consistent across all three procedure based cohorts. However, as mentioned before, the significance of the cohort differences are best determined at the regional level.

Clearly, examining the patient cohort is not sufficient to determine whether a hospital can be classified as a high-tech research facility. More appropriate measures of a high-tech teaching hospital are 1) high rates of procedure utilization, 2) early treatment adoption rates for new treatments such as stents and statins, and 3) better outcomes. These measures should not be compromised by underlying heterogeneity to the same extent as the data on patient characteristics were. By comparing these three measures for the U.S. average and the average from the teaching hospital, it is possible to ascertain whether the teaching hospital conforms to our standards for a leading high-tech hospital. We will begin with comparison of the procedure utilization rates.

Looking at the treatment trajectories of patients after they receive CAG, we find significantly higher rates of procedure utilization at the teaching hospital compared to the national average. Of the patients who received CAG at the teaching hospital, approximately 70% received PCI within the same admission, approximately 17-11.5% received CABG and only 15% to 10% received no treatments. Compared to the national average, where of the patients who received CAG, only 3% to 4% received PCI, only 5.50% – 6.73% received CAGB, and most patients (74% - 71.5%) received no medical treatment at all during the first admission, the teaching hospital appears to be better equipped to respond quickly to the needs of patients during their stay at the hospital. The rates of procedure use by IHD patients within a year after CAG remain high in the teaching hospital (PCI: 69.11% in 1994 to 74.21% in 1998; CABG: 18.36% in 1994 to 12.70% in 1998; no treatment: 12.96% in 1994 to 9.13% in 1998) while the U.S. average increased for PCI to 34% in 1994 and 43% in 1998, decreased for CABG (29.13% in 1994 to 26.17% in 1998) and for patients who received no treatments (28.82% in 1994 to 22.33% in 1998). Please see Chart 1 and Chart 2 for graphical illustration of these trends for all years. Part of the increase in treatment rate for the U.S. average in the year following CAG can probably be account for by the fact that many patients who received CAG were subsequently transferred to a facility like the teaching hospital that had the equipment necessary to perform the requisite procedures. Likewise, the high rates of procedure utilization of patients admitted to the hospital during their initial stay probably reflects the fact that many patients were transferred to the hospital specifically to receive PCI or CABG.

Another characteristic of leading research teaching hospitals is the early adoption of state-of-the-art medical technology. Though it can be difficult to identify patterns of early technology adoption, the introduction of stents, a mesh-like device inserted into diseased arteries to maintain blood flow, in the mid 1990's make it possible to study this effect. In Chart 3, our data shows that stents were not used in PCI surgery in the U.S. or in research hospital in 1994. Beginning in 1995, stents started to be used across the United States at a rate of 7.23% in IHD patients who had received CAG. Comparatively, in the same year, doctors in the research hospital used stents at a rate of 10.80%. The following year revealed another large increase in the use of stents, 41.67% in the U.S., and 47.65% at the research hospital. In 1997 and 1998, the U.S. rate surpassed the rate of stent use in the research facility, however, we can speculate that the slowing rate of increase in the teaching hospital reflects changing physician practice patterns rather than the unavailability of the technology. In the first two years of stent usage, the data do seem to indicate a pattern of earlier adoption as seen in the more rapid increase of stent utilization rates.

Finally, by comparing patient outcomes, we gain a sense of the relative quality of care available at the teaching hospital and in the U.S. as a whole. In general, we will be looking at the outcomes associated with PCI following CAG, since the small sample size for patients receiving CABG following CAG is potentially biased by random fluctuations in the patient cohort from year to year. On the whole, we find that patients treated in the teaching hospital had fewer complications and better outcomes than did the average IHD patient in the United States. First, the time from admission to PCI has steadily decreased for both cohorts; however, the absolute time frame is shorter for patients in the teaching hospital. In 1994, the mean wait was 0.73 days, decreasing to 0.41 days in 1998 at the teaching hospital. A similar patient in the U.S., on the other hand, waited 1.85 days in 1994 for the procedure, down to 1.24 days in 1998. Perhaps because of this difference, patients who received PCI at the teaching hospital spent approximately 1.5 to 2 fewer days in the hospital during their original hospital stay (4.01 days in 1994; 2.14 days in 1998) than the national average (5.76 days in 1994; 4.02 day in 1998). This trend of decreasing length of stays for patients receiving PCI continued for the first 30 days after the initial hospitalization (U.S. average: 6.51 days in 1994; 5.12 day in 1998; hospital average: 4.60 days in 1994; 2.54 days in 1998) and for the year after the initial hospitalization (U.S. average: 9.47 days in 1994; 8.71 days in 1998; hospital: 6.23 days in 1994: 4.43 days in1998). The shorter length of stay in the teaching hospital could be attributed to many factors: governmental policies that reward physicians and hospitals for decreasing patient stays, the high levels of managed care in the area surrounding the hospital, a healthier patient cohort, fewer procedure related complications and a lower readmission rate, among other factors. While it is not within the scope of this study to explore how the first three factors affect patient length of stay, it is possible to review rates of procedure-related complications and re-admissions.

The 30-day complication rates were relatively similar in the U.S. and the teaching hospital; less than 1% of patients from either cohort had complications within 30 days of their procedure. We see more of a difference in the 365-day complication rates, although the rates are still low for both cohorts. Post-operative MI occurs slightly more frequently in the average U.S. IHD patient (5.30% in 1994; 7.48% in 1998) than in a patient at the research hospital (4.70% in 1994; 4.01% in 1998). Rates of acute occulusion for the U.S. are between 0.85% in 1994 and 1.37% in 1998. In the teaching hospital, these rates seem to be dropping rather than rising (0.63% in 1994; 0.27% in 1998). While it is probable that the lower complication rates at the research hospital play a part in the lower length of stays that we describe above, re-admission rates may have a more direct impact on length of stays. At the teaching hospital, there is a decreasing rate of readmission due to cardiac-related incidents for both 30-day and 365-day re-admissions. In 1994, 2.51% of the IHD patients who received PCI following CAG were readmitted within 30 days and 7.21% were readmitted within 365 days. Comparatively, in the same year, 2.69% of U.S. IHD patients who received PCI following CAG were readmitted within 30 days and 9.16% within one year. These rates are not too different, but looking forward four years to 1998, we see that while the readmission rates have decreased or stayed approximately level in the teaching hospital, they have increased in the country as a whole. In the teaching hospital, the 30-day readmission rate decreased to 1.60% and the 365-day rate basically remained level at 7.47%. For the U.S. IHD patients, 30-day re-admissions increased to 4.19%, and 365-day re-admissions to 11.22%.

Finally, comparing mortality rates, we find that the rates remained more or less level for the U.S. patients and decreased in the teaching hospital's patients, making the differences in mortality rates more pronounced over time. The 30-day mortality rate is 3.22% in 1994 and