A Cost-Benefit Analysis of the Bone Marrow Registry

By: Chelsea Swete
Faculty Sponsor: Damien Sheehan-Connor, Economics Department

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INTRODUCTION

Bone Marrow Transplants are life-saving operations for people with blood diseases such as leukemia. They can only be performed if the donor and recipient have compatible immune systems.

Human Leukocyte Antigens (HLA) are the part of the immune system that helps the body identify its own cells. The type of HLA produced is controlled by alleles on chromosome 6; the more matches at these alleles the more similar two individuals' immune systems are. Transplant doctors currently look at 4 genes: A, B, C, and DRB1. The distribution of combinations of alleles at these genes vary by race; generally minority populations have a more diverse distribution of types. The probability of two randomly selected individuals from the general population matching exactly is below:

Race	Caucasian	African-American	Asian-American	Hispanic
Caucasian	1 / 5,000			
African-American	1 / 188,000	1 / 229,000		
Asian-American	1 / 1,723,000	1 / 65,242,000	1 / 59,000	
Hispanic	1 / 66,000	1 / 1,331,000	1 / 11,372,000	1 / 140,000

The NMDP (National Marrow Donor Program) runs a registry of about 8 million people and stores information about their HLA types. The chance that a patient requiring a transplant will have an exact match with a sibling is ¼. For those who don't have a sibling match (about 4,500 per year), doctors search the registry for a donor.

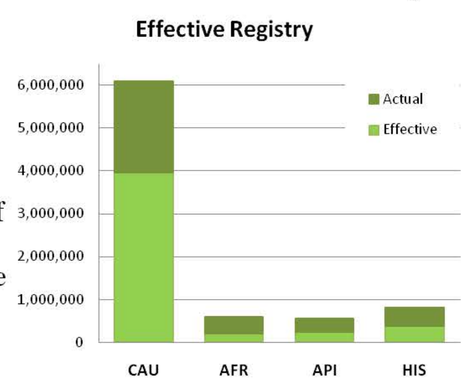
GOAL

- Update the Cost-Benefit Analysis of adding registrants from "One in a Million" [1] with new data with an additional gene (C) and at a higher resolution (4 digits)
- Calculate the exact probability that an individual of a certain race will have an 8/8 or 7/8 match on the registry

METHODS

Effective Registry

Not all of the 8 million people on the registry donate when asked. Some are unable to for health reasons, some can't be Located, and some are unwilling. An **effective registry** is the actual amount of registrants multiplied by the fraction of people available to donate when asked.



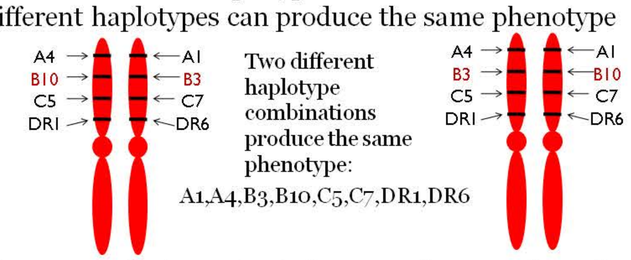
Actual Registry	6,090,000	600,000	561,000	800,000
Fraction Available	0.57	0.27	0.35	0.34
Effective Registry	**3,471,300**	**162,000**	**196,350**	**272,000**

METHODS CONT

Phenotypes and Frequencies

Background:

- **Haplotype**: set of 4 (A, B, C, DRB1), inherit one from each parent
- **Phenotype:** set of 8 alleles (two at each gene), result of combination of two haplotypes
- different haplotypes can produce the same phenotype



- Current medical standards for transplant require at least 7/8 of the alleles on the phenotype to match

Process:

- Combine Maiers' 8,879 estimated haplotype frequencies [2] by race to calculate frequencies of 12,397,248 phenotypes
- Create separate matrices allowing a mismatch at each gene (7/8 match)
- Use frequencies to find the probability of an exact 8/8 match and at least a 7/8 match on the current registry

Costs

- Hospital Costs for new transplants ($166,000 each)
- HLA typing for effective registrant
  - It costs $105 to add an individual to the registry because of the DNA test to determine type. To get the cost of an effective registrant: $105/(fraction available)

Benefits

- Change in probability of finding a match by adding 1 more registrant of specific race
- Increased chances of survival with transplant
  - No match → 7/8 = .21 [1]
  - 7/8 → 8/8 = .05
- Value of a Statistical Life (we use $9,000,000 [3])
- Number of people in need of transplant

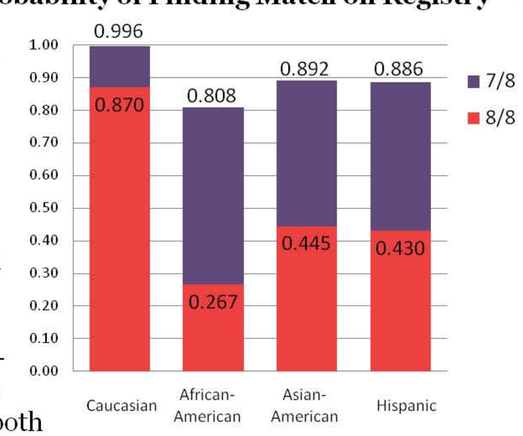
Costs:	Effective Registrant	Yearly Hospital
Caucasian	$184	$11
African-American	$389	$52
Asian-American	$300	$27
Hispanic	$309	$38

Average Annual number in need of transplant	
Caucasian	3401
African-American	392
Asian-American	205
Hispanic	425

PRELIMINARY RESULTS

Probability of Finding Match on Registry

Caucasian patients have a much higher chance of finding a match on the current registry, especially when looking for exact 8/8 matches, which give the highest expected chance of survival. African-Americans have the lowest chances for both 8/8 and 7/8 matches.



PRELIMINARY RESULTS CONT

Adding one registrant of this race...

Adds this social benefits to members of this race	Caucasian	African-American	Asian-American	Hispanic
Caucasian	$29	$0	$0	$1
African-Am	$1	$147	$1	$5
Asian-Am	$0	$0	$72	$1
Hispanic	$1	$5	$1	$97
TOTAL	**$30**	**$153**	**$74**	**$103**

The benefits and costs of one additional registrant were calculated with the assumption that the average registrant will be on the list for 25 years (the average list age is 35 and people are automatically dropped off after they turn 61[1]) and a discount rate of 2%.

	Caucasian	African-American	Asian-American	Hispanic
Benefit	$600	$3,039	$1,482	$2,061
Cost	$246	$1,433	$620	$794
Net Benefit	**$1,397**	**$7,071**	**$3,620**	**$5,214**
B:C Ratio	**2.4**	**2.1**	**2.4**	**2.6**

CONCLUSIONS

- There is an economic argument for continuing to add more registrants of all races to the NMDP list because all of the benefit-cost ratios are greater than one and all of the net benefits are positive.
- Adding minority registrants contributes the greatest net benefit.
- Another way to increase the number of lives saved by transplants is by increasing the effective registry through increasing the fraction of registrants available to donate.

FUTURE DIRECTIONS

- Expand analysis to include cord blood registries
  - -Cord Blood Transplants are an alternative to bone marrow transplants; the units require expensive storage and there are only about 95,000 [2], but they only require 6/6 matching
  - -Calculate optimal size
  - -Suggest variable pricing parameters
- Expand analysis to include probabilities for individuals of mixed race

References

[1]Bergstrom, Theodore C., Garratt, Rodney J., and Sheehan-Connor, Damien. 2009. "One Chance in a Million: Altruism and the Bone Marrow Registry." *American Economic Review*, 99(4): 1309–34.

[2]Maiers, Martin, NMDP, Personal Communication.

[3]Viscusi, W. Kip, and Joseph E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." *Journal of Risk and Uncertainty, 27(1): 5–76.* (updated to $2009)

Acknowledgments

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