Public Citizen's Health Research Group

and the

American Medical Student Association

Report on Hospital Bias in the National Resident Matching Program (NRMP)

September 1995

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How the NRMP Operates

The National Resident Matching Program (NRMP) is a systematic process guided by a specific set of rules (an algorithm) that, with the help of a computer, produces a set of "matches" between graduating medical seniors and hospital residency programs. The NRMP is managed and operated by the Association of American Medical Colleges. Students rank the residency programs they would like to attend in descending order of preference, with their first choice at the top of the list. Hospital residency programs do the same with the students; the most preferred student is placed at the top of the list, the least preferred at the bottom. For both students and hospitals, unacceptable programs or students are not listed. The lists are then submitted to the NRMP, the algorithm is applied to the lists collected nationally from the students and the residency programs, and a matching result is produced.[1]

There are many different matching systems, or algorithms, through which the two groups' preference lists (also called rank-order lists) could be matched to one another. Depending upon the exact nature of the algorithm used to match the two groups together, differing outcomes may result.[2,3,4] The NRMP uses a specific algorithm, and a result is produced consistent with the properties of that algorithm.

The outcome of any matching algorithm can be described in terms of being "stable" or "unstable."[2,3,4,5] A stable match possesses two basic properties: first, "there can be no student and hospital who *both* prefer each other over the assignments they will receive."[2] That is, in a stable match, neither party has incentive to break their contracts, as a more preferable choice is not available. Second, no student or hospital is matched with a partner they consider unacceptable (i.e. no on their rank-order list). Historically, unstable matches have not survived because the parties involved find that they can secure more preferable placements outside of the program--confidence in the program is eroded and eventually it is abandoned altogether.[3] The NRMP algorithm produces a stable match, and in order to retain the confidence of the participants it must obviously continue to do so.

An important property of a stable algorithm is that it must be able to resolve conflicts that occur between the participant's preference lists.

Example 1

Student 1's List	Student 2's List	Hospital A's List
H-A	H-A	S-1
		S-2

For example, suppose that Student 1 has ranked hospital A as her first choice and Student 2 has also ranked Hospital A at the top of his list. If Hospital A ranked Student 1 as the first choice and Student 2 as the second choice, a conflict exists. Obviously in order for the result to remain stable, Student 1 is matched to Hospital A. In this example there is exactly one stable outcome.[6]

In the more complex preference conflicts among larger groups of participants with longer rank-order lists,* there exist variations in how an algorithm can resolve these conflicts, while still providing a stable outcome (see example 2 below). In a certain percentage of these conflicts a stable resolution can be obtained at the expense of one group and to the benefit of the other group.[2,7,8] The formal terminology to describe an algorithm's built-in bias for one of the participating parties and against the other party is "optimal" and "pessimal," respectively. In the specific case of matching graduating medical seniors to residency programs, the terminology becomes "hospital-optimal/student-pessimal" (the algorithm currently in use), or "student-optimal/ hospital-pessimal".[2] Again, whether the algorithm is student-optimal or hospital-optimal depends on the specific algorithm in use.

Not only can these stable algorithms contain a bias, they may also contain "opportunities" for the participants to affect, positively or negatively, their final outcome by misrepresenting their true preferences.[2,4] In other words, they may list a false set of preferences in hopes of obtaining a better placement on their actual or true preference list. The NRMP and its algorithm can be thought of as the rules to a game with the hospital and the students acting as players (a game with important consequences, as the outcome greatly affects careers and lives). As in any game, strategies exist whereby participants may attempt to obtain the best possible outcomes for themselves. Some stable algorithms expose both parties to these incentives; some expose only one of the two groups of participants--no

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* *The NRMP algorithm must deal with thousands of students and hundreds of hospitals--a more complex situation compounded by "match variations." (See endnote 9.) Supplemental rank lists, one of the match variations, allows students to match to two positions simultaneously in a given run of the Match. This became necessary as programs that begin in the second year post graduation (PGY-2) started to participate in the Match in the early 1980s. This required an interested student to match to both a PGY-2 program and a preliminary first year program. Couples matchings, a matching variation where couples can be matched to programs in close proximity to one another, adds another twist.*

algorithm removes all incentives to misrepresent for all participants.[4]

The Inherent Bias Against Applicants Is Not Explained

The NRMP admits in the series of articles on the Match in *Academic Medicine* that when the NRMP was implemented in 1952, very little was known about the mathematics of preference matching.[9] Since 1952, examination of preference matching in other fields has demonstrated that "stable" preference matching, as applied in the NRMP, can utilize algorithms that run a spectrum between two basic extremes--one favorable to the group of hospitals running the residency programs and one favorable to the group of students applying to these programs. None of the authors in the *Academic Medicine* series disagrees that the current matching algorithm used by the NRMP is essentially a hospital-optimal algorithm.[2,9]

With this mathematical fact established, it is understood that conflicts will arise in the process of returning a stable outcome from a set of rank-order lists. The example that follows demonstrates the differences in how a hospital-optimal and a student-optimal algorithm would return the matching results.

Example 2

Student 1's List	Student 2's List	Hospital A's List	Hospital B's List
H-B	H-A	S-1	S-2
H-A	H-B	S-2	S-1

In the above chart, the desires of the students as a group conflict with the desires of the hospitals as a group. Examination reveals that two, and only two, stable matches are possible: (1) both hospitals get their first choice (hospital-optimal solution). In this stable solution, the hospitals' first choices are matched to the students' second choices. Student 1 is matched at Hospital A and Student 2 is matched at hospital B. Notice that the conditions to make this match stable are fulfilled; there does not exist a hospital *and* student who *both* would rather be matched with each other than with their current assignments, and neither hospital nor student were matched to an unacceptable preference; or (2) both students get their first choices (student-optimal solution). In this case the exact reverse of the hospital-optimal match is true.[6]

Regardless of the additional complications that arise when increasing numbers of students and hospitals are added to the algorithm and "match variations"[9] are included (i.e. supplemental rank lists and couples matching), the current NRMP algorithm remains, at its core, a hospital-optimal one. Fairness demands that both groups clearly understand the implications of this and their positions relative to one another prior to entering the program.

Contrary to what Peranson, president of the National Matching Services, Inc. and Randlett, deputy executive director, National Resident Matching Program, say, the present explanation offered to students entering the match is not a clear representation of the true nature of the Match. NRMP literature over many years has stated "each applicant is matched to the hospital program highest on the applicant's rank order list that has offered the applicant a position" (1995 NRMP Handbook, p.A2.1), which implies that students do as well as possible. An expanded explanation offered by Peranson and Randlett reads:

> *Hospital programs thus offer positions 'down' their rank order lists until they fill their positions or have no more applicants. Applicants accept positions 'up' their rank order lists until they are matched to their most preferred programs that offered them positions.*[10]

A nearly identical passage can be found in the 1996 NRMP student handbook.[1] This "explanation" is not, as Peranson and Randlett claim, "a clear statement... of the bias inherent in the hospital-optimal algorithm."[10] On the contrary, it appears that the exact opposite impression is given to students entering the matching program. In 1993, students from the University of Pennsylvania produced a *Survival Guide to The Match* to help "graduates navigate the rough waters of the Match...." The revised, 1994 edition of the guide advises students to "List programs in order of your true preference.... [because] It [the computer] really is on your side!" The guide further states, in complete contradiction to the NRMP's above admission of the algorithm's hospital-optimal bias, that "The computer always gives the student's list priority over the hospital's list." Obviously the current "clear" statement is not clear enough.

The 1996 NRMP Handbook claims that "The principle and matching algorithm upon which the Matching Program functions are straightforward."[1] If this is, in fact, the case then it should be stated with equal clarity: The National Residency Matching Program utilizes a "hospital-optimal" algorithm, that is, it contains an inherent bias in favor of the hospitals.

While it is agreed that those not affected by this include students matching to their true first choices, those not matching, and students matching into programs that are not entirely filled (these students will receive the same assignment under either algorithm),[2,9] a certain, significant percentage of students do not fit these criteria and are therefore exposed to an incentive to misrepresent their true preferences. Which specific individual students this will be and how many of them will be penalized in a given match can only be estimated without actual rank-order lists. One estimate places the "exposed" group at close to 17%. That is, 1 in 6 of the more than 15,000 U.S. medical students entering the match each year might have had their assignments improved under a student-optimal algorithm.[2]

An Incentive for Applicants to Misrepresent True Preferences

With a hospital-optimal algorithm, it is not always the best strategy for all applicants to always list true preferences.[8,11] While referring back to Example 2 in the previous section, suppose Student 1 omits Hospital A from her preference list. The algorithm can then generate only a single stable solution instead of the two that were previously possible (the hospital-optimal and student-optimal outcomes). Further supposing that the algorithm in our new example is set up in the hospital-optimal form (the current NRMP algorithm), it becomes clear that Student 1 will have forced a "student-optimal" outcome from an algorithm with a hospital-optimal bias: because of Student 1's misrepresentation, both student's will receive their true first preferences.[6]

Students lack the information necessary to know how best to alter their preference lists and thereby maximize their chances with the current algorithm, yet they remain exposed to an algorithm that will penalize some of them for listing all of the programs they would be willing to attend. A consideration by the student of how lengthy a list to submit to the NRMP is a prime example of this: submitting too long a list may be detrimental to the student trying to secure a placement as high on his or her list as possible, while a shorter list increases the risk of not matching at all.[10]

The handbook provided by the NRMP instructs applicants to "rank programs in the order that they prefer beginning with rank #1 for the most preferred program.... and [applicants] should rank all programs that are desirable..."[3] What it fails to explain is that for a certain segment of the applicants, as is illustrated in Example 2, by stating all the hospitals they desire to match to in descending order of preference, they may be penalized by being matched to a less desired program than if they had not followed the NRMP instructions.

A purely student-optimal matching system shields the applicants from the "incentives" to misrepresent their true preference--the original justification for creating the match in 1952.[9,12] The NRMP must clearly state in the literature to applicants that the current hospital-optimal algorithm is structured in such a way that they may be penalized for stating their true preferences. They must also make it known that a student-optimal algorithm could be used that would remove these penalties.

Unrealistic Nature of the NRMP's Algorithm

It has been asserted in the past and continues to be a contention that "the NRMP algorithm, in which preference is given to hospital choices when conflicts in rankings occur, duplicates what happens in an actual orderly admissions process without a computerized matching program."[3,9] In other words, the claim is that the NRMP is only a "passive facilitator" of a process that occurs regularly in common situations, such as applying for a job or applying for admission to college or medical school. Thus, the NRMP claims that their hospital-optimal bias mimics "real-life" orderly admission processes.

The basic premise of these types of comparisons is false: the NRMP is not a passive facilitator in the process of pairing graduating students with residency programs, nor does the NRMP duplicate the conditions found in medical school admissions--a non-centralized** process.

The college and medical school admissions process possesses properties that make its direct comparison with the match spurious. In the non-centralized setting, in an effort to reduce the risk of underfilling, medical schools and colleges tend to make more offers than they have positions. This, in turn, leads to a danger of overfilling. The "gambling" that the schools engage in--an effort to judge how many acceptances they will have to extend in order to satisfactorily fill the open positions--creates excess offers that work to the benefit of the applicants.[8,13] Depending on the competitiveness of the school, the ratios of offers to available positions in medical schools range from about 1.5:1 to 3.5:1.[2] This provides an advantage to the applicants that the Match algorithm actively eliminates.

While once more referring to Example 2, suppose that either hospital issued an extra offer and thereby created a ratio of two offers to one position--a situation and ratio realistic for a college or medical school.[6] Notice that the outcome becomes student-optimal with both Student 1 and Student 2 receiving their first choices. The Match algorithm actively eliminates these extra offers, and protects hospitals from the necessity of behaving in this fashion. The obvious result is the elimination of this advantage to students.

Why Student-Optimal?

Because the claim that the current NRMP algorithm and its hospital-optimal bias acts as a "passive facilitator" and "closely emulate[s] the process that would occur without a centralized matching mechanism"[9] is invalid, the algorithm cannot be represented as some sort of product of the "natural" applicant-employer bargaining relationship, nor can its continued existence be defended on this premise. It is clear that the matching algorithm has created a situation that is unnaturally advantageous to hospitals.

The direction in which the algorithm bias should lie now becomes the obvious question. There are several compelling reasons why a student-optimal algorithm would be a fair and more reasonable choice of stable algorithms than the current hospital-optimal

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** *A non-centralized system such as college and medical school admissions can be distinguished from a centralized process such as the NRMP by the order it imparts to the process (often accomplished with the aid of a computer). The NRMP collects all rank-order lists from students and hospitals by a specific deadline and generates all final matches for all participants simultaneously. In college and medical school admissions, no such system exists and final placements are accomplished in a decentralized fashion with acceptances and refusals spread over a period of months, involving communication between applicants and institutions, with no "central clearinghouse."*

algorithm. First, the historical basis for choosing the current algorithm was to eliminate the emphasis the pre-Match process placed on the students' strategic ability as a factor in residency placement. As an orderly, centralized system, the current hospital-optimal algorithm has somewhat ameliorated this strategic component though it still retains some of the incentives for students to misrepresent their preferences; a student optimal-algorithm would remove these incentives and complete this goal.

Second, since it is impossible to remove all the incentives for hospitals to misrepresent, it would be best to choose the student-optimal algorithm to remove incentives, at least for students. In other words, within the set of stable algorithms, you either have incentives for both the hospitals and the students to misrepresent their true preferences or only for the hospitals.

Third, there is reason to believe that hospitals are not as particular about precise assignments as are individual students and would subsequently lose very little in a student-optimal algorithm.

Finally, there is evidence that minority students are disproportionatly at risk from the hospital-optimal algorithm's bias. Minority students tend to match with less frequency to their stated first choices than other groups of students.[14] Because of this, a significantly larger portion of them are exposed to the negative effects of the hospital optimal bias.*** Granted, changing the algorithm to a student-optimal one will not deter any given hospital from composing a preference list under racially biased considerations (this falls outside the algorithm's sphere of influence). What it would do though is remove the unbalanced, added negative effects levied against minority students made possible by the hospital-optimal algorithm.

The original justification for creating the match was to protect students from an incentive to misrepresent their true preferences. Before the match was created, students were forced to accept positions at hospitals earlier and earlier in their undergraduate education as hospitals scrambled to fill positions in their programs--some "reportedly signing up interns still in the sophomore year of medical school."[15] Students had to continually make the choice between accepting a less preferred program that had offered them a position or declining the offer--at the risk of not receiving another--in hopes of receiving an offer in the future from a more preferred program.[7,16] This created a situation where the student's ability to assess his or her chances and play the waiting game became

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*** *Remember that under the hospital-optimal algorithm the students matching to their stated first choices, students not matching, and students matching into programs that are not filled will not be affected by changing to a student-optimal algorithm. In other words all students not fitting these criteria are exposed to the bias and can only improve their position or retain the same position under a student-optimal algorithm.*

paramount. This incentive to misrepresent is still present in the current algorithm; it was not extinguished with the creation of the centralized matching program due to the NRMP's choice of algorithm. As was stated above, it is possible to effectively accomplish the original goal and remove this incentive by using a student-optimal algorithm.

Not only was this original justification for the Match not realized, but it appears that the students entering into the Match at its inception in 1951-52 did so under the false impression that the algorithm was not biased against them.[17] In the graduating year prior to the official implementation of the Match, a "dry run" was performed "without influencing the procedures already in effect."[15] The algorithm used in this trial run was met with some objection on the part of the students, and as a result, a student committee was formed. This committee won changes in the original (1950-51) matching plan.[16,17,18] The altered matching plan was implemented for the 1951-52 match and exists to this day, albeit with some minor alterations, in the same form.

Dr. Jack G. Schiller, who graduated from Columbia College of Physicians and Surgeons in 1952, recalled that the student protest originated in the students realizing, once the original, dry-run algorithm was described to them, that the computer produced an unfair "edge" for the hospitals. The algorithm that Dr. Schiller describes as being the one in contention in 1950-51 is not extinct; it is what is in place today: the hospital-optimal algorithm. Dr. Schiller and the students apparently incorrectly assumed that the alterations they had achieved in the 1950-51 algorithm in time for the 1951-52 match had removed this unacceptable bias.[17]

The student-optimal algorithm would provide the best possible scenario to limit the incentives of either party to misrepresent their choices--a desirable property, as misrepresented preferences tend to destablize a match.[4] Most hospitals (specifically, those with two or more positions offered in a residency program) will always retain incentives to misrepresent their true preferences regardless of the algorithm.[4] As the current algorithm stands, both individual hospitals and individual students have the potential of improving their final outcome by misrepresenting their true preferences on their rank-order lists. If the student-optimal algorithm was in fact implemented, strategy would no longer be a factor in compiling a rank-order list, and a given graduating student would have the freedom of placing each and every school he or she found desirable in his or her true order of preference with no potential of penalty--an originally stated and as yet unrealized goal of the NRMP. The uncomfortable guesswork that goes into "composing a list not too long...but not too short" would be a thing of the past.

A student-optimal algorithm would likely produce less negative effects for the hospitals than the hospital-optimal algorithm currently does for students. A student-optimal algorithm would fill a given residency program in a hospital to the same extent and most of the student assignments would be the same within that program. In addition to these buffers, there is reason to think that a hospital is less sensitive to exact assignments than are individual students, since hospitals tend to select on objective criteria (i.e. test scores,

grades, etc.). Contrast this with an individual student who, unlike the hospital, possesses only one "slot" or "assignment," namely himself or herself. The current hospital-optimal algorithm may assign them a lower ranked choice on their preference list, thereby imposing significant alterations in where the student will live, for example, and raising significant social and financial considerations--considerations that do not affect hospitals as institutions.

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September 6, 1995

Jordan Cohen, M.D.
President, AAMC
Association of American Medical Colleges
2450 N Street, NW
Washington, DC 20007

Dear Dr. Cohen:

A recent series of articles in the journal, *Academic Medicine,* has brought into focus a serious recurring question in the administration of the National Residency Matching Program (NRMP). As the American Association of Medical Colleges is the responsible administrator of the NRMP, the purpose of our letter is to bring to your attention the immediacy of the problem and to negotiate a course of action to remedy the inequities in the system on behalf of the nation's medical students.

In conjunction with the recent articles published, the American Medical Student Association and Public Citizen have conducted a review and prepared a technical paper on the hospital-biased algorithm issue. (attached) In brief, we would request that the AAMC and NRMP take the following immediate actions:

1. The NRMP algorithm should be switched immediately from its current hospital-optimal algorithm to a student-optimal algorithm. This switch must be subject to outside verification. More than 15,000 students enter the match each year. Just as tens of thousands of students may have been affected during the 44 years that the hospital-optimal algorithm has been in effect, thousands of students may be assigned lower rankings on their preference lists in this year's Match.

Our support for a student- rather than hospital-optimal algorithm is based on the fact that the impact is much greater on a student than it is on a residency program. An internal medicine program with ten residency slots will not suffer substantially from getting their 15th versus 16th ranked student. On the other hand, a student's Match result can influence their entire future: whether or not they are near their loved ones and family, benefit from a specific teaching environment, are required to move, or are able to find employment for their significant others, etc....

2. The authentic rank-order lists of students and hospitals must be provided to an independent panel where matching outcomes from the current algorithm can be evaluated. We recognize the need for confidentiality and see no need for the revelation of student indentities. This will provide solid data on the extent to which students have been impacted by the current algorithm. Equally as important,

this will allow for the evaluation of alternative algorithm models that would be student-biased.

The NRMP's commitment to evaluate internally the fairness of the current match system is suspect in light of their reluctance to do so when presented years ago with information on the biased nature of the algorithm and the existence of incentives for applicants to misrepresent their preferences. NRMP workers were informed of the bias as early as 1976 when David Gale sent a copy of his 1962 publication (Gale, D. and Shapley. L.S. *Am. Math. Monthly 69* (1962) :9-15). The findings that incentives to misrepresent existed in the type of algorithm used in the matching program were brought to the attention of the NRMP no later than 1984 (Roth, A. E. *Math Oper. Res. 7 (1982):617-628).* The NRMP can strengthen the confidence the medical community has placed in it by speedily subjecting authentic rank-order lists to scrutiny by an outside, impartial party and making the results public.

Public Citizen and the American Medical Student Association have combined forces to bring this matter to a fair conclusion acceptable to medical students. We are prepared to bring the issue of the hospital-biased algorithm to the attention of the total medical student and faculty communities through a national educational campaign. If necessary, we will institute a petition drive to galvanize student, faculty and administrative support of a student-optimal algorithm.

We are eager to enter into a meaningful and constructive dialogue with the AAMC and NRMP as soon as possible to discuss the issues. We respectfully ask that you respond to us by October 1, 1995. If we do not hear from you by the specified date, we will pursue an alternative course of action as outlined above.

Sincerely Yours,

Lydia J. Vaias, M.D.

Lydia J. Vaias, M.D.
President, American Medical Student Association

Sidney Wolfe, M.D.
Director, Public Citizen's Health Research Group

Randy Sasich
Researcher, Public Citizen's Health Research Group
Medical Student, Georgetown University School of Medicine