

Early vs Single Match in the Transition to Residency: Analysis Using NRMP Data From 2014 to 2021

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ABSTRACT

Background An Early Result Acceptance Program (ERAP) has been proposed for obstetrics and gynecology (OB/GYN) to address challenges in the transition to residency. However, there are no available data-driven analyses on the effects of ERAP on the residency transition.

Objective We used National Resident Matching Program (NRMP) data to simulate the outcomes of ERAP and compare those to what occurred in the Match historically.

Methods We simulated ERAP outcomes in OB/GYN, using the de-identified applicant and program rank order lists from 2014 to 2021, and compared them to the actual NRMP Match outcomes. We report outcomes and sensitivity analyses and consider likely behavioral adaptations.

Results Fourteen percent of applicants receive a less preferred match under ERAP, while only 8% of applicants receive a more preferred match. Less preferred matches disproportionately affect DOs and international medical graduates (IMGs) compared to US MD seniors. Forty-one percent of programs fill with more preferred sets of applicants, while 24% fill with less preferred sets of applicants. Twelve percent of applicants and 52% of programs are in mutually dissatisfied applicant-program pairs (a pair in which both prefer each other to the match each received). Seventy percent of applicants who receive less preferred matches are part of a mutually dissatisfied pair. In 75% of programs with more preferred outcomes, at least one assigned applicant is part of a mutually dissatisfied pair.

Conclusions In this simulation, ERAP fills most OB/GYN positions, but many applicants and programs receive less preferred matches, and disparities increase for DOs and IMGs. ERAP creates mutually dissatisfied applicant-program pairs and problems for mixed-specialty couples, which provides incentives for gamesmanship.

Introduction

The transition to residency has become costly in time and money.¹ Virtual interviews have reduced some costs but increased the number of interviews. Several proposals suggest ways to increase the efficiency of applications and interviews.²⁻¹⁰

One proposal, for residency recruitment in obstetrics and gynecology (OB/GYN), is the Early Result Acceptance Program (ERAP).¹¹⁻¹³ ERAP would be an optional, binding “early match” in which applicants submit a limited number of applications to OB/GYN programs, which proponents suggest would promote more in-depth consideration of applications. Residency programs could offer up to half their positions early. The standard application, interview, and match processes would follow for applicants and programs unmatched after ERAP.

ERAP proposers hypothesize that an early match would ease the burden of applications and interviews, allowing for holistic review of applicants.^{11,14} Critics have raised concerns about destabilizing the Match,¹⁵ increased applications and stress, and potentially stigmatizing applicants who do not match early.¹⁶

We report the first data-driven analysis of ERAP, using full National Resident Matching Program (NRMP) rank order list (ROL) and Match data from 2014 to 2021. Through computer simulation, we modeled how OB/GYN applicants and programs would have fared with ERAP vs the historical (actual) match for each year. We explain how *blocking pairs* (ie, mutually dissatisfied applicant-program pairs) are inevitable in an early match with a fraction of positions available and discuss how such destabilization historically led to *unraveling* of recruitment processes.

Methods

Data

De-identified ROLs and Match results from 2014 to 2021 for all residency programs and applicants,

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Editor's Note: The online version of this article contains further data from the study.

across all specialties, were provided by the NRMP (including ROLs for single applicants and couples).

TABLE 1 describes applicant and program match populations from 2014 to 2021. For example, in the 2021 NRMP Match, 294 OB/GYN programs offered 1478 positions. A total of 2039 applicants ranked OB/GYN programs, and of those, 1880 were single applicants, 1773 of whom were *OB/GYN-preferring*, having listed an OB/GYN program as their first choice. A total of 414 applicants listed both OB/GYN and other specialties, with family and internal medicine being most common, and 294 of these applicants ranked both OB/GYN and non-OB/GYN programs in their top 5 choices. Of the 1773 applicants who listed OB/GYN as their first choice, 307 ranked multiple specialties. One hundred and ninety-four of these applicants ranked a non-OB/GYN program in their top 5 choices. Out of the 2039 applicants, 159 entered the match as members of a couple. Only 3 couples had both members of the couple ranking OB/GYN programs.

Matching Algorithm Validation

We programmed the Roth-Peranson algorithm used by the NRMP.¹⁷ To provide validity evidence for the

Objectives

We used National Resident Matching Program data to simulate the outcomes of the Early Result Acceptance Program (ERAP) and compare those to what occurred in the Match historically.

Findings

Simulations showed that the ERAP would create a substantial number of mutually dissatisfied applicant-program pairs, leaving a large percent of applicants with a less preferred match.

Limitations

The study assumes that historical data mirrors applicants' and programs' future preferences.

Bottom Line

The results suggest that an ERAP match would destabilize the market, open the door to rule-breaking behavior, and destabilize the Match in subsequent years, disproportionately affecting DOs and IMGs and creating tough decisions for multispecialty couples.

algorithm, we reproduced the single-round match with ROLs provided by the NRMP and compared this to the actual outcome that occurred in each historical NRMP Match. In every year, the reproduction of the single-round match resulted in identical outcomes for at least 98.7% of individual applicants

TABLE 1
Descriptive NRMP Match Statistics for OB/GYN Applicants and Program (2014-2021)

Statistics	2014	2015	2016	2017	2018	2019	2020	2021
Single Applicants								
Submitted ROLs	1692	1700	1623	1605	1720	1879	1842	1880
Ranked other specialties	380	367	371	331	383	408	431	414
Ranked OB/GYN and other specialties within top 5	256	252	250	216	243	266	264	247
Top choice OB/GYN	1519	1543	1480	1493	1590	1756	1714	1773
US MD Seniors	900	955	888	972	966	1031	1029	1042
US DO Seniors	154	156	141	140	201	258	213	236
IMG (US & non-US citizen)	226	199	186	145	146	152	141	149
US Grad (US medical school graduates from prior years)	32	23	37	17	24	30	28	39
Ranked other specialties	207	210	228	219	253	285	303	307
Ranked other specialties within top 5	140	144	159	154	158	192	178	194
Family medicine	114	119	133	113	157	151	138	163
Internal medicine	79	66	82	81	77	91	107	90
Average ROL length	9.9	9.9	10.4	10.5	10.5	10.3	10.7	11.2
Couples								
One member ranks OB/GYN	110	126	134	149	165	153	173	156
One member ranks OB/GYN as their top choice	106	122	130	144	161	145	163	149
Both rank OB/GYN	1	5	5	5	2	3	3	3
Programs								
Programs	250	250	254	258	272	280	289	294
Positions	1263	1275	1286	1309	1357	1412	1460	1478
Average ROL length per program	58.9	62	61.4	62.3	62.1	63	62.2	65.8
Average ROL length per position	11.7	12.2	12.1	12.3	12.4	12.5	12.3	13.1

Abbreviations: NRMP, National Resident Matching Program; OB/GYN, obstetrics and gynecology; ROL, rank order list; IMG, international medical graduate.

and at least 99.94% of couples compared to the historical NRMP outcomes. For OB/GYN applicants, fewer than 0.05% of applicants received different outcomes than their actual NRMP matches. This provided validity evidence for the reproduced algorithm. Note that the slight incongruity in outcomes is expected due to the presence of couples whose joint ROLs may impact the final match due to arbitrary ordering decisions needed to confirm that the Match algorithm converges.

Simulating the ERAP Proposal

We simulated ERAP through a computer model (programmed in C#) that included an early match followed by a main (regular) match, using each season's NRMP ROLs as input. We used the same model to reproduce the current single-round match for comparison (as above). At each round, we ran the Roth-Peranson matching algorithm. In the early match, only OB/GYN-preferring applicants were included. In the main match, applicants to all specialties were included. In the simulation, we excluded matches from the Supplemental Offer and Acceptance Program (SOAP). ERAP was simulated as follows:

Early Match Round: Each OB/GYN-preferring applicant applies to the top 5 OB/GYN programs from their original NRMP ROL, or all of them if they ranked fewer than 5 OB/GYN programs. Each OB/GYN program offers 50% of its available positions (rounding down if needed), except for programs offering only one position, in which case the single position is included in the early match. Programs use their actual NRMP ROLs to rank applicants.

Applicants who match and program positions that fill in the early round are considered matched and excluded from the "main match" round. Sensitivity analyses evaluated alternative application limits, positions available, and alternative specifications of program ROLs.

Main Match Round: Following the early match, all ERAP-unmatched OB/GYN applicants and all unfilled OB/GYN programs enter the main residency match, along with applicants and programs from all other residency specialties. OB/GYN programs offer positions that were unfilled in the early match round. Other specialties' programs include all positions. Applicants and programs submit their actual NRMP ROLs.

Couples' Matching: In the early match, members of couples interested in OB/GYN are treated as singles,

using their original NRMP ROL to approximate their preferences. Note that almost all couples are mixed-specialty couples, where one member applies in OB/GYN and the other in another specialty. In the main match, partners of OB/GYN couple members (who matched in the early round) enter as singles. Reported ROLs approximate applicants' preferences.

Finally, we compared the simulated 2-round ERAP and single-round match outcomes for OB/GYN for each year (2014-2021) as if the early match had been introduced in that year (ie, without modeling any strategic adjustments that might result after the first year of the early match). Each year was analyzed separately to demonstrate the likely variability of future outcomes.

The study was reviewed by the Stanford Institutional Review Board (IRB 56742), which determined that the study of these de-identified data does not require consent from applicants or programs.

Results

In each year (2014-2021), the percentage of OB/GYN positions filled in the early match (among those offered early) was between 98% and 99%. Both the simulated ERAP and single-round match filled more than 98.5% of all positions. We report here the analysis based on 2021 outcomes, but results for all years are included (TABLE 2 and FIGURE 1).

Applicant and Program Preferences Outcomes

Applicants: Of the 1773 OB/GYN-only preferring applicants, 138 (7.8%) received a more preferred position in ERAP overall than the single-round (traditional) match, while 256 (14.4%) of applicants received a less preferred position (more and less preferred refer to an applicant's placement on their historical ROL). Of the 625 OB/GYN-only preferring applicants who matched in the early ERAP round, only one applicant received a more preferred outcome, while 188 received a less preferred outcome. The remaining 436 (70%) who matched in the early ERAP round matched to the same program as in the single (traditional) match. FIGURE 1 shows the number of applicants who received more or less preferred outcomes by year, stratified by applicant type: US MD Senior, US DO Senior, IMG (international medical graduate, including US IMGs), and US Grad (US medical school graduates from prior years). Using US MD Seniors as a benchmark, the results from US DOs, IMGs, and US Grads were 68.1%, 121.8%, and 150.4% more matched to less preferred positions, respectively. The results are robust to the inclusion of non-OB/GYN-preferring applicants in ERAP, with

TABLE 2
Summary of Simulation Results

Value	2014	2015	2016	2017	2018	2019	2020	2021
Single applicant (top choice OB/GYN) outcomes								
More preferred, n (%)	129 (8.5)	136 (8.8)	137 (9.3)	123 (8.2)	142 (8.9)	119 (6.8)	143 (8.3)	139 (7.8)
More preferred who matched early, n	0	1	0	1	0	1	1	1
Less preferred, n (%)	227 (14.9)	226 (14.6)	242 (16.4)	232 (15.5)	229 (14.4)	250 (14.2)	239 (13.9)	256 (14.4)
Less preferred who matched early, n	166	146	183	153	164	162	160	188
Programs' outcomes, %								
More preferred	37.2	37.2	37.4	38.8	33.5	37.1	37	41.5
Less preferred	22.8	28.4	21.7	25.6	26.5	27.1	30.8	23.8
Mixed	20.8	16.4	22.8	15.5	19.9	15	11.1	14.3
Couples' outcomes, %								
One matched early	46.4	38.1	45.5	46.3	42.4	30.7	40.5	37.2
Unacceptable outcome when one matched early	35.3	31.2	27.9	23.2	21.4	19.1	12.9	22.4
Couples in mutually dissatisfied pairs	21.8	19.8	18.7	22.8	23	14.4	15	12.2
Couples receiving more preferred	11.8	14.3	10.4	10.7	12.1	16.3	9.2	7.1
Couples receiving less preferred	27.3	25.4	28.4	31.5	27.3	20.9	25.4	19.2
Single applicants in mutually dissatisfied pairs								
Single applicants in mutually dissatisfied pairs, n (%)	205 (13.5)	162 (10.5)	203 (13.7)	187 (12.5)	182 (11.4)	187 (10.6)	183 (10.7)	205 (11.6)
Single applicants who matched early, n (%)	205 (38.4)	162 (29.9)	203 (38.1)	183 (33.9)	181 (32.4)	184 (30.5)	179 (29.7)	201 (32.2)
Single applicants who matched late, n (%)	0 (0)	0 (0)	0 (0)	4 (0.6)	1 (0.1)	3 (0.4)	4 (0.5)	4 (0.5)
Mutually dissatisfied pairs among singles with less preferred matches, %	70.9	61.1	73.1	65.9	67.7	61.6	66.9	70.3
Programs in mutually dissatisfied pairs, %	54.4	52.8	60.2	58.9	52.9	49.6	54.3	52.4
Programs with more preferred outcomes: percentage that match with an applicant in a mutually dissatisfied pair, %	91.4	78.5	83.2	83	89	80.8	81.3	75.4

Abbreviation: OB/GYN, obstetrics and gynecology.

Note: The first 2 sections provide statistics about OB/GYN single applicants and programs that received more or less preferred outcomes in the simulated 2-round Early Result Acceptance Program (ERAP) match compared to the simulated single-round match. More or less preferred refer to an applicant's outcome in the simulated ERAP vs the match they received on their historical rank order list. The third section displays couples' outcomes in the simulated 2-round ERAP match. The fourth and fifth sections provide the percentage of single applicants who are part of mutually dissatisfied pairs and percentage of programs in blocking pairs. The last 2 sections provide statistics that further inform why and where mutually dissatisfied pairs arise.

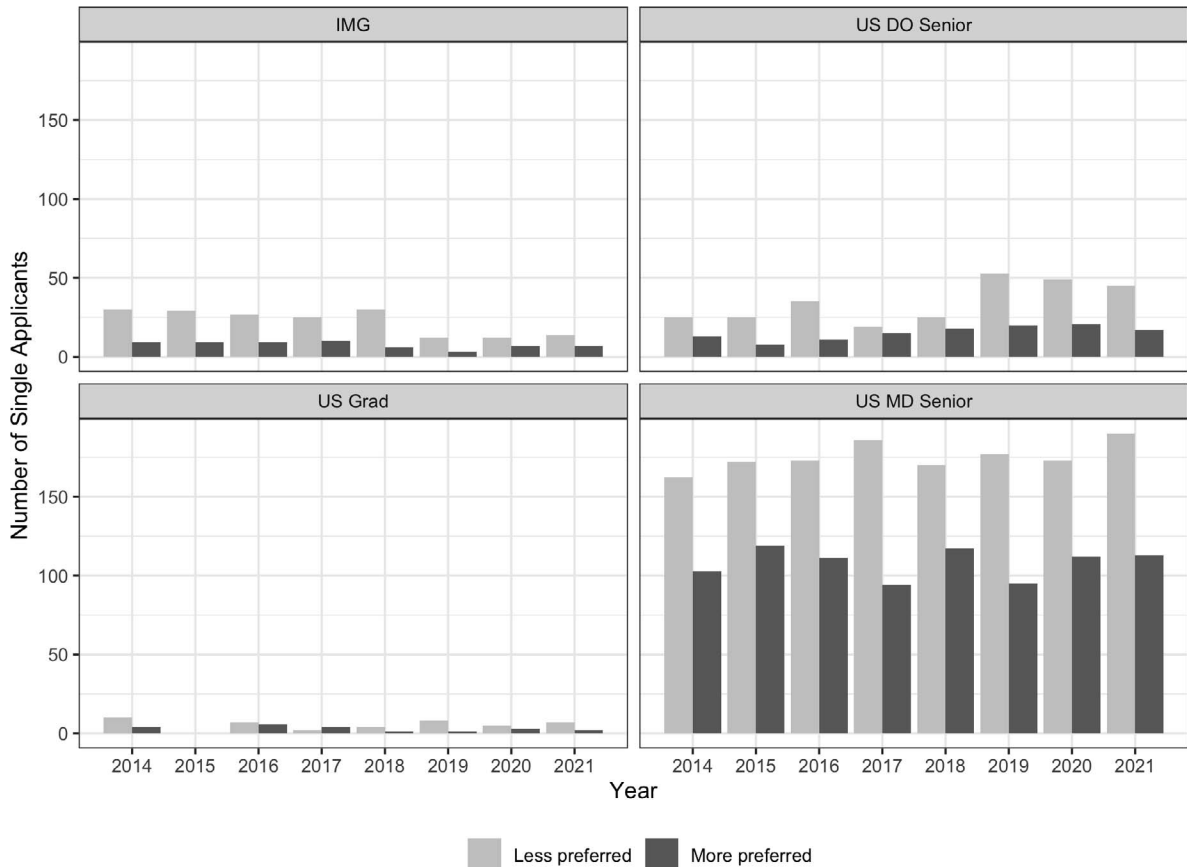


FIGURE 1
Simulations Outcomes by Applicant Group

Note: Number of obstetrics and gynecology single applicants who received more preferred (right, dark gray column) and less preferred (left, light gray column) outcomes in the 2-round Early Result Acceptance Program (ERAP) match simulation compared to their outcomes in the single-round match simulation. More or less preferred refer to an applicant's outcome in the simulated ERAP vs the match they received on their historical rank order list. US DO, international medical graduate (IMG), and US Grad (US medical school graduates from prior years) groups have disproportionately less preferred outcomes than US Seniors through an early match. For instance, taking the mean over years of $(1 - [\text{less preferred DO}/\text{more preferred DO}]) / [\text{less preferred US Senior}/\text{more preferred US senior}] * 100$, we find that US DOs experience 68.1% less preferred outcomes on average. For IMGs and US Grads those averages rise to 121.8% and 150.4%, respectively.

only 4 in this category obtaining different match outcomes.

Programs: Of the 294 OB/GYN programs, 2 programs filled a different number of positions under the 2 scenarios. One hundred twenty-two (41.5%) programs received a more preferred outcome in ERAP overall than the single-round (traditional) match (ie, for each applicant in the program's single-round match, there exists a distinct applicant of equal or higher rank in their ERAP match). Seventy programs (23.8%) had less preferred outcomes with ERAP (ie, the program's match results were nonidentical; all applicants that matched were ranked lower by the program). Sixty programs (20.4%) filled with an identical set of applicants with ERAP, while 42 (14.3%) had mixed outcomes (ie, the program matched some combination of more and less

preferred applicants based on their historical rank lists). Every year, except 2021, fewer programs received more preferred outcomes than either a less preferred or a mixed outcome, with ERAP.

Couples: Of the 156 of 159 couples with only one member preferring OB/GYN, 58 (37.2%) matched early with ERAP. Thirty (19.2%) couples received a less preferred match with ERAP. Thirty-five (22%) couples whose non-OB/GYN-preferring member matched in the main match would have achieved a joint outcome not listed on their original joint ROL (ie, at a pair of programs they had not indicated as an acceptable match). This may happen if only one partner matches early, then the 2 partners are effectively participating as 2 single applicants (OB/GYN-preferring in the early ERAP, the other in the main match).

Mutually Dissatisfied Applicant-Program Pairs

A mutually dissatisfied pair consists of an applicant who didn't match to a more preferred program, and their preferred program, which also would have preferred this same applicant, compared to at least one of the other matched applicants. That is, both the applicant and the program would have preferred each other to their ERAP-determined match. In economics, this is referred to as a "blocking pair." The current NRMP Match, governed by the Roth-Peranson algorithm, provides a "stable matching" outcome that generally contains no blocking pairs.

With the 2-round ERAP match, 205 (11.6%) of the 1773 single (traditional) match applicants who ranked an OB/GYN program first on their ROL became part of mutually dissatisfied pairs. One hundred eighty (70.4%) single applicants who received a less preferred outcome were part of a mutually dissatisfied pair, and 154 (52.4%) of all OB/GYN programs were in mutually dissatisfied pairs at the end of the 2-round ERAP match. Notably, 92 (75.4%) of 122 programs that received a more preferred outcome were assigned an applicant who was part of a mutually dissatisfied pair (with a different program).

ERAP results in the creation of previously non-existent blocking pairs. By instituting a 2-round match, 205 (11.6%) of the 1773 single applicants who ranked an OB/GYN program first on their ROL were part of mutually dissatisfied pairs. Two hundred one of the applicants in such pairs matched early, while 4 matched in the main match. Eighty-eight percent (225 of 256) of applicants who received a less preferred outcome were part of a mutually dissatisfied pair. Approximately 52% (154 of 294) of all OB/GYN programs are in mutually dissatisfied pairs at the end of the 2-round ERAP match. Notably, 75.4% of programs that received a more preferred outcome were assigned an applicant who was part of a mutually dissatisfied pair (with a different program).

Sensitivity Analysis

We varied the application limit in the early round from 1 to 6 applications ($k=1-6$, online supplementary data). Some single applicants receive more preferred outcomes, but even more receive less preferred outcomes as k increases (eg, when $k=3$, 6.4% receive more preferred outcomes and 10.6% receive less preferred outcomes). As k increases, more applicants are in mutually dissatisfied pairs (eg, for $k=3$, 8.3%), and more mutually dissatisfied pairs are present among applicants who match early (eg, for $k=3$, 17.7%). Note the opposite trend is observed among applicants who

match in the ERAP main match round. Couples' outcomes are similar for all values of k .

We also varied the percentage of positions offered in the early round from 20% to 80% ($P=20\%$ to 80%, online supplementary data). The smaller the value of P , the more mutually dissatisfied pairs are present among applicants who match early. As the value of P increases, more couples with one member preferring OB/GYN match early.

Robustness

This simulation assumes applicants and programs will interview and rank programs, in the context of an early match and ERAP, similarly to how they acted in the historical single-round match. Applicants might not apply early to all programs, and programs might not consider every applicant who applies in the early round. To relax these assumptions, we simulated ERAP under 3 models. In model 1, OB/GYN-preferring applicants apply in the early round only to OB/GYN programs higher on their ROL than any non-OB/GYN program, and to no more than 5 programs. In model 2, programs rank only applicants in the top $k\%$ ($k=50, 30, 10$) of their original ROL. In model 3, programs consider only their preferred $k\%$ ($k=50, 30, 10$) of applicants who applied. The first model demonstrates robustness with respect to mutually dissatisfied pairs. In models 2 and 3, the percentage of applicants receiving less preferred outcomes, or part of mutually dissatisfied pairs, decreases substantially only when the percentage of early round unfilled positions increases (TABLE 3). That is, the harms measured in this analysis are those caused by early matches, and they decline only when early matches decline.

Discussion

Our simulation study of ERAP, a novel proposal to address the growing challenges of residency recruitment, shows that a 2-round match would not affect the number of positions filled in the match. However, it would alter which applicants match at which program and generate mutually dissatisfied, applicant-program pairs. Additionally, more applicants would match to less preferred programs, with DOs and IMGs disproportionately affected, and strategic challenges for couples would be created.

The NRMP Match and algorithm allows multispecialty applications and couples matching, including mixed-specialty couples matching. The algorithm results in a stable final match (ie, there are no mutually dissatisfied applicant-program matches). This approach promotes participants stating their true preferences on ROLs. There is a considerable

TABLE 3
Robustness Test for 2021

Model	Considered by Program, %	Positions Unfilled Early, %	Single Applicants More Preferred, %	Single Applicants Less Preferred, %	Single Applicants in Blocking Pairs, %	Programs in Blocking Pairs, %	One Couple Member Matched Early, %
Model 1	100	1.6	8.2	13.2	11.4	52	37.2
Model 2	50	2.8	7.6	14.4	11.3	52.4	37.8
	30	6.1	7.5	14.1	10.7	50.3	37.2
	10	23.9	7.3	12.4	9.4	47.3	28.8
Model 3	50	13.9	7.4	12.7	10.4	48	24.4
	30	23.8	7.2	12	9.2	45.9	21.8
	10	55.2	6.3	9.1	5.8	40.1	13.5

Note: When programs consider a limited number of applicants in the early round. Model 1: Obstetrics and gynecology (OB/GYN)-preferring applicants apply in the early round only to OB/GYN programs higher on their rank order list (ROL) than other non-OB/GYN program, and to no more than 5 programs. Model 2: Programs rank only applicants in the top k% (k=50, 30, 10) of their original ROL. Model 3: Programs consider only their preferred k% (k=50, 30, 10) of their applicants who applied.

body of evidence from other markets and from the history of the NRMP that these properties are critically important for the orderly and successful operation of the Match.¹⁸⁻²⁰ Our simulation findings suggest that ERAP will not maintain these properties. In this ERAP simulation, because only 50% of a program’s positions are available in the early round, applicants who would have matched with a program if more of its positions were available may match

early with a program they prefer less. Similarly, programs may match applicants who are less preferred. Since matches are binding, this often creates mutually dissatisfied pairs (FIGURE 2).

The early match alone does not produce mutually dissatisfied pairs (ie, non-stable matches); this occurs with the combined early and late matches. Proponents of ERAP hoped to continue NRMP’s stable matches by using the Roth-Peranson algorithm for both matches.¹⁴ However, because of the binding nature of the early match, this simulation shows that mutually dissatisfied matches are likely to occur, and most of these will occur in the early match cycle. A primary concern with mutually dissatisfied applicant-program pairs is that they provide incentives for outside-the-match bargaining in subsequent years. This issue led to the creation of the NRMP in 1952. Bargaining behaviors have been observed in medical matching in the United Kingdom and in other matching markets with artificial capacity constraints, such as sorority matching at US universities. In short, matching procedures that produce mutually dissatisfied pairs have a history of failure.²⁰⁻²⁵

Strategic behaviors caused by mutually dissatisfied pairs may not be limited to one specialty. For example, 17% of OB/GYN-preferring applicants rank other specialties, and 63% of these historically rank another specialty in their top 5 ROL choices. These applicants would not be able to express their full preferences in the limited choices in the early ERAP match. This situation and concerning behaviors have been observed in ophthalmology and urology, which have earlier matches through non-NRMP services. It is also difficult to speculate how this would impact combined specialties (eg, pediatrics/anesthesiology, internal medicine/psychiatry, etc). ERAP creates strategic challenges for couples, 98%

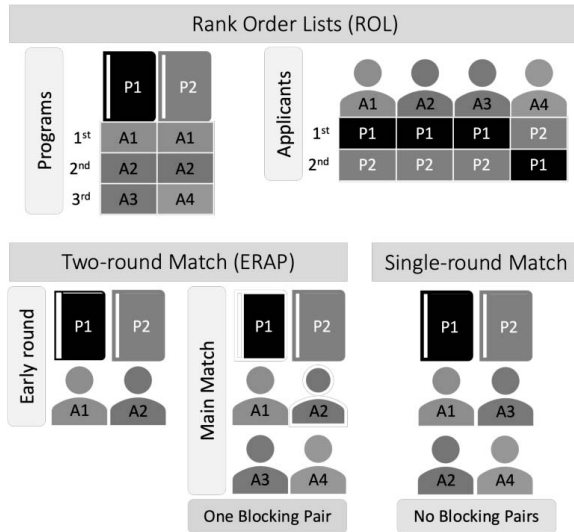


FIGURE 2
Example Demonstrating the Creation of a Single Blocking Pair in an Early Result Acceptance Program

Note: The rank order lists of programs and applicants are given in the top of the figure (Applicants [A1-A4], Programs [P1-P2]). Both programs P1 and P2 offer 1 position in the early round of the Early Result Acceptance Program (ERAP). In the early round A2 cannot match with P1 and matches with P2. In the main round of ERAP, P1 matches with A3. So A2 and P1 are a mutually dissatisfied pair: P1 would prefer to match A2 over A3. A2 would prefer to match at P1 over P2. This was generated because P1 did not offer all positions in the early round. Note that in a single-round match, there are no mutually dissatisfied pairs.

of which are mixed-specialty couples. Such couples will need to consider the implications of the OB/GYN-preferring partner matching early, which creates a scenario whereby the non-OB/GYN-preferring partner enters the main match as a single applicant. Couples thereby may adapt their ROLs to avoid matching in an unacceptable pair of programs, or consider forgoing ERAP or matching into OB/GYN entirely.

If early matches were widely adopted, many of the benefits of the NRMP would be lost, renewing the incentives for unraveling, including by couples (but not limited to couples), and creating further challenges for DOs and IMGs to apply on a level playing field.²⁵

Limitations to this study include the assumption, used in the simulation, that historical ROLs would mirror future applicant and program preferences in ERAP, in either early or late ERAP rounds. This includes effects on ROLs pre- and post-interview. It is also challenging to determine the change in satisfaction an applicant or program would experience in matching at a position on their ROL compared to a program at a lower position. It is likely that applicants would consider many factors (including, but not limited to, chance of match and program preferences) when selecting a limited number of applications in the early match round. These unknown factors, including the burden on applicants and programs to participate in 2 matches, were not considered in the simulation (eg, 2 applicants with identical ROLs may differ in how much they prefer each program, leading to different behaviors under ERAP). Behaviors of couples, after the early match round, are similarly unknown but may include change in match strategy or arranging for a residency position directly (as couples needed to do before the introduction of the couples' match). It is also possible that not all OB/GYN applicants or programs would choose to participate in ERAP. This, together with the limit on the number of applications, could possibly allow programs to spend more time reviewing applications, which may impact their ROLs.

Future research steps may include simulating the effects of preference signaling that several specialties are piloting, as these strategies are more aligned with the stability of the match. Additionally, more in-depth study of the factors influencing applicant and program decisions to interview and create ROLs is needed.

Conclusions

This simulation of the proposed OB/GYN ERAP found that more applicants received less preferred match outcomes and created mutually dissatisfied applicant-program pairings, which disproportionately

affected DOs and IMGs and created tough decisions for multispecialty couples. These results suggest that an ERAP match would destabilize the market, open the door to rule-breaking behavior, and destabilize the Match in subsequent years.

References

1. Carmody JB, Rosman IS, Carlson JC. Application Fever: reviewing the causes, costs, and cures for residency application inflation. *Cureus*. 2021;13(3):e13804. doi:10.7759/cureus.13804
2. Salehi PP, Heiser A, Salehi P, et al. Ideas and innovations to improve the otolaryngology-head and neck surgery residency application and selection process. *Otolaryngol Head Neck Surg*. 2021;164(5):1001-1010. doi:10.1177/0194599820961989
3. Watson SL, Hollis RH, Oladeji L, Xu S, Porterfield JR, Ponce BA. The burden of the fellowship interview process on general surgery residents and programs. *J Surg Educ*. 2017;74(1):167-172. doi:10.1016/j.jsurg.2016.06.008
4. Gadepalli SK, Downard CD, Thatch KA, et al. The effort and outcomes of the pediatric surgery match process: are we interviewing too many? *J Pediatr Surg*. 2015;50(11):1954-1957. doi:10.1016/j.jpedsurg.2015.06.008
5. Love ER, Dexter F, Reminick JI, Karan SB. Reducing over-interviewing in the anesthesiology residency match. *Cureus*. 2021;13(8):e17538. doi:10.7759/cureus.17538
6. Chang CD, Pletcher SD, Thorne MC, Malekzadeh S. Preference signaling for the otolaryngology interview market. *Laryngoscope*. 2021;131(3):e744-e745. doi:10.1002/lary.29151
7. Salehi PP, Salehi P, Michaelides E. Preference signaling in the national resident matching program—reply. *JAMA Otolaryngol Head Neck Surg*. 2018;144(10):951-952. doi:10.1001/jamaoto.2018.1559
8. Bernstein J. Not the last word: want to match in an orthopaedic surgery residency? Send a rose to the program director. *Clin Orthop Relat Res*. 2017;475(12):2845-2849. doi:10.1007/s11999-017-5500-9
9. Morgan HK, Winkel AF, Standiford T, et al. The case for capping residency interviews. *J Surg Educ*. 2021;78(3):755-762. doi:10.1016/j.jsurg.2020.08.033
10. Melcher ML, Ashlagi I, Wapnir I. Matching for fellowship interviews. *JAMA*. 2018;320(16):1639-1640. doi:10.1001/jama.2018.13080
11. Hammoud MM, Andrews J, Skochelak SE. Improving the residency application and selection process: an optional early result acceptance program. *JAMA*. 2020;323(6):503-504. doi:10.1001/jama.2019.21212

12. Association of Professors of Gynecology and Obstetrics. Transforming the UME to GME Transition: Right Resident, Right Program, Ready Day One. Accessed February 16, 2023. <https://apgo.org/page/transformingtheumetogmetransition>
13. Winkel AF, Morgan HK, Akingbola O, et al. Perspectives of stakeholders about an early result acceptance program to complement the residency match in obstetrics and gynecology. *JAMA Network Open*. 2021;4(10):e2124158-e2124158. doi:10.1001/jamanetworkopen.2021.24158
14. Hammoud MM, Andrews JS, Skochelak SE. An early result acceptance program for residency application—reply. *JAMA*. 2020;323(22):2345-2345. doi:10.1001/jama.2020.6516
15. Adler C. An early result acceptance program for residency application. *JAMA*. 2020;323(22):2344-2345. doi:10.1001/jama.2020.6513
16. Clements DS. Weighing the benefits and unintended consequences of a 2-phased match. *JAMA Network Open*. 2021;4(10):e2124400-e2124400. doi:10.1001/jamanetworkopen.2021.24400
17. Roth AE, Peranson E. The redesign of the matching market for American physicians: some engineering aspects of economic design. *Am Econ Rev*. 1999;89(4):748-780. doi:10.1257/aer.89.4.748
18. Roth AE. What have we learned from market design? *Econ J*. 2008;118(527):285-310. doi:10.1111/j.1468-0297.2007.02121.x
19. Roth AE. The economist as engineer: game theory, experimentation, and computation as tools for design economics. *Econometrica*. 2002;70(4):1341-1378. doi:10.1111/1468-0262.00335
20. Royal Swedish Academy of Sciences. Stable Allocations and the Practice of Market Design. Accessed February 16, 2023. <https://www.nobelprize.org/uploads/2018/06/advanced-economicsciences2012-1.pdf>
21. Roth AE. New physicians: a natural experiment in market organization. *Science*. 1990;250(4987):1524-1528. doi:10.1126/science.2274783
22. Roth AE. A natural experiment in the organization of entry-level labor markets: regional markets for new physicians and surgeons in the United Kingdom. *Am Econ Rev*. 1991;81(3):415-440.
23. Harner CD, Ranawat AS, Niederle M, et al. AOA symposium. Current state of fellowship hiring: is a universal match necessary? Is it possible? *J Bone Joint Surg Am*. 2008;90(6):1375-1384. doi:10.2106/JBJS.G.01582
24. Cannada LK, Luhmann SJ, Hu SS, Quinn RH. The fellowship match process: the history and a report of the current experience. *J Bone Joint Surg Am*. 2015;97(1):e3. doi:10.2106/JBJS.M.01251
25. Roth AE, Xing X. Jumping the gun: imperfections and institutions related to the timing of market transactions. *Am Econ Rev*. 1994;8(4):992-1044.



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