Transplant Matching

User manual

Version: 1.0

5. 10. 2021

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Information about the manual

The manual is intended for all authorized users of the **IKEM Transplant Matching** application.

Manual version

View Full Version	Date of issue	Version description and changes compared to the previous version
Version: 1.0	5. 10. 2021	Initial version of the manual for version 1.4.19 of **Transplant Matching**.

About the app

IKEM Transplant Matching is a web-based application accessible via standard web browsers.

Note: Microsoft Internet Explorer is not supported. The recommended screen resolution is FullHD (1920x1080) or higher.

The app displays the optimal matching of living donors and kidney recipients calculated by the system, even from different countries.

Note: Users with **editor** and **administrator** privileges can change the default conditions for pairing and for displaying pairing results.

See chapter **Workflows - Configuration**.

The following algorithm is used to calculate the optimal pairings:

Central to the **Transplant Matching** application is an algorithm that searches for the optimal matching of kidney donors and recipients.

Summary

This algorithm finds all compatible transplants between donors and recipients and then selects the combination that is the largest in terms of the number of compatible transplants and meets the specified conditions. This combination is the optimal matching. Since the combinations that have the largest number of compatible transplants are usually several, we introduce an extra score. Based on the given criteria, we compute the score for each transplant and then select the optimal pairing that has the largest sum of the scores of the individual transplants.

The algorithm can be configured through the configuration in the user interface.

Detailed description

More precisely, the algorithm for finding the optimal pairing works as follows:

1. Determination of permissible transplants

   We use all donor-recipient combinations in a given TXM event to determine which transplants are allowed. A transplant is permissible if all of the following apply:

   a. Donor and recipient do not have a positive virtual HLA crossmatch. The crossmatch is calculated using the donor's antigens and the recipient's antibodies and is positive if the recipient has an antibody to any of the donor's antigens. If the crossmatch is at a level that is set by the **allowed crossmatch types** parameter, the transplant is allowed, however, it is marked with a red warning icon in the user interface.

   b. Donor and recipient have matching blood types. We distinguish between:

      i. *By compatible blood group* we mean that the blood group is compatible according to the standard ABO scheme, where blood group 0 has a universal donor and blood group AB has a universal recipient.

      ii. *Acceptable blood group*, which means that the blood group does not have to be compatible but is set as acceptable in the recipient's settings. Compatible blood type is always acceptable, but the reverse is not true.

      Whether we require a compatible blood group is determined by the **require compatible blood group** parameter, which can be set in the configuration. Otherwise, we only require an acceptable blood type.

c. The donor and recipient countries must not be set as forbidden **country combinations** in the configuration.

d. The transplant score is not manually set to -1. The score can be manually set in the configuration in the **manual scores for donors and recipients** section. This is useful for disabling a particular transplant in the resulting pairing.

e. In addition, if the parameter **require new donor having better CI match than original donor** or **require new donor having better CI match than original donor or blood group match** is set in the configuration, the resulting transplant is required to be better than the original donor transplant in terms of score size or score size or blood group.

2. Calculation of the score

For each eligible transplant, we calculate its score. The score is calculated based on matches between donor and recipient typing. The minimum score is 0 and the higher the score, the better the transplant. The specific way in which the score is calculated can be set using the **scorer** in the configuration. If the numeric parameter **compatible blood group bonus** is set in the configuration and the donor and recipient have a compatible blood group, the transplant score is additionally increased by the specified value. If **manual scores for donors and recipients** is set for this transplant, the transplant score is set to the specified manual value and the scorer is not used in this case. An unacceptable transplant is represented by a score of -1.

3. Finding the optimal pairing

First, we look for the **top** matchings that contain the highest number of transplants. We rank the pairings with the same number of transplants by the sum of the scores of the contained transplants. Each matching consists of non-overlapping transplants that are divided into **cycles and sequences**, which we uniformly call **rounds**. A cycle is defined as a transplant where each donor has an original recipient in a previous transplant. The donor in the first transplant has its original recipient in the last transplant. This implies that there are no **bridging donors** or **non-directed donors** in the cycle. In contrast, the sequences contain a donor in the first transplant that does not have an original recipient (bridging donor or non-directed donor). In the configuration you can set the maximum number of transplants in a cycle (**max cycle length** parameter) or the maximum number of transplants in a sequence (**max sequence length**). In addition, the matching found must match the following constraints that can be set in the configuration:

a. Contains all recipients set in the **required recipients** configuration.

b. The score of each transplant must be at least the number set by the **minimum transplant score** parameter.

c. Each country must have a difference between the number of donors and recipients in the matching (which we call debt) of at most **max country debt**.

d. Patients can be from a maximum of **max countries in round** different countries in one cycle or sequence.

The number of best matches that are calculated can be set using the **maximum number of matchings** parameter. The best matchings are technically computed using an *oriented graph* and an algorithm that can be set using the **solver** parameter. The solver *ILPSolver*, which is set as default in the application, solves this problem using integer programming and is based on the paper *Finding long chains in kidney exchange using the traveling salesman problem*[1]. The second type of solver is *AllSolutionsSolver*, which solves the problem by browsing through all the allowable pairings and then selecting the best one. Because the number of allowable pairings is often uncountable and the computation can get stuck, we recommend using ILPSolver.

[1)] *Anderson, Ross, et al. "Finding long chains in kidney exchange using the traveling salesman problem." Proceedings of the National Academy of Sciences 112.3 (2015): 663-668.*

WORKFLOWS

Login to the system

1. In the address bar of your web browser, type the URL of the application https://txmatching.ikem.cz/ and press **enter**.

   Tip: It is advisable to put the address of the application in your "favourites" ("bookmarks") and call the application from there.
2. The login form will appear.
3. Enter your email address and assigned password.
4. Press the **Submit** button.
5. You will then receive an SMS with a verification code.
6. Enter the code from the SMS in the **Verification code field**.
7. Press the **Verify** button.

If you have entered the verification code correctly, you will be logged into the system and the **Top Matchings** home page will be displayed.

See also the chapter **Pairing overview**.

Your login remains valid until you log out. After ten days, you are automatically logged out.

See **Exiting the application and logging out of the system**.

Configuration

Users with the **editor** or **administrator** role can change the pairing recalculation settings and also affect how pairings are displayed.

I can then set the modified configuration as the default for the selected pairing round.

See the chapter **Saving the default configuration for the selected pairing round**.

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1. If you don't currently have the **Top Matchings** overview displayed, please display it.

   See the **Pairing Overview** chapter.
2. Click **CONFIGURE**.
3. **The Confuguration** modal window appears, containing a form to set pairing requirements and display pairings as needed:
   - Use the switches to set the pairing requirements:
     - **Require compatible blood group** - When enabled, a compatible blood group according to the standard ABO scheme will be required for pairing (for example, blood group A or 0 will be required for blood group A). When turned off, the list of *acceptable blood groups* set for each patient will be used to select the required blood group.

 See also the chapters Editing recipient record parameters and Adding new patients.

- **Require new donor having better CI match than original donor** - When enabled, the new donor will be required to have a better Compatibility Index (CI) value than the original donor.
- **Require new donor having better CI match than original donor or blood group match** - When enabled, the new donor will be required to have a better CI value than the original donor match or compatible blood group.
- **Use binary scoring** - When enabled, binary scoring (0 and 1) will be used for transplants.
- **Use High resolution** - When enabled, split resolution will be used when searching for antibodies.

- Set or enter other required parameters:
  - **Maximum matchings to show to viewer** - The maximum number of calculated matchings to show to a user with the **viewer** role. Set to 0 if you want the user with the viewer role not to see the calculated matchings.
  - **Max countries in round** - The maximum number of different countries allowed in one transplant series (round = cycle or sequence).
  - **Max country debt** - The maximum difference between the number of donors and recipients from a given single country.
  - **Max country debt for blood group zero** - The maximum difference between the number of donors and recipients from any one country with blood group 0.
  - **Solver** - An algorithm that will solve the optimal matching problem to find the resulting matching.

    AllSolutionsSolver - *The* algorithm goes through all the possible solutions and lists the best ones.

    ILPSolver - Algorithm using inductive logic programming.

     See the description of the algorithm in the chapter **Introduction -** About the application.
  - **Maximum number of matching** - The number of best solutions to be calculated (the higher the number, the longer the calculation takes).
  - **Max cycle length** - The maximum number of transplants per round that form a cycle (consisting of donor-recipient pairs only).
  - **Max sequence length** - The maximum number of transplants per round that do not form a cycle (starting with a bridging or non-directed donor and ending with the creation of a bridging donor).
  - **Minimum transplant score** - The minimum score that each transplant must have.
  - **Compatible blood group bonus** - The bonus score that is added when transplanted with a compatible blood group.

     See also the chapters Editing recipient record parameters and Adding new patients.

- **Forbidden country combinations** - Patients of the combinations defined here (selected countries) will not be paired as donors and recipients.
  - ADD NEW COMBINATION - To define a forbidden combination, set the donor country and recipient country by selecting them, then press the **Add +** button. You can add other combinations in the same way.

To remove a defined combination, click the icon next  to the combination.

- **Manual scores for donors and recipients** - Manually set scores for a specific pair of patients.

- ADD NEW MANUAL SCORE - Select the desired donor and recipient, enter the score and press the **Add +** button. You can set the score for other pairs in the same way. A score of -1 means that the transplant is impossible (useful for manually scoring a particular pair).

On the other hand, to remove a defined pair, click on the icon next to the pair.

- **Required recipients** - Only **matchings** containing the recipients set here will be displayed in the matching report.
  - Required recipients - When you click into the item, a menu of recipients will appear. Select the desired recipient. The item acts as a filter, as soon as you start typing the patient ID into the item, the recipient menu will be limited to only patients whose ID contains the specified characters. Define all recipients that are required in all resulting **matchings in this way**.

To remove a recipient from the list, click the icon next to the desired recipient identifier.

4. To save the set parameters, press the **Set values** button at the bottom of the modal window.

If you want to close the window without saving any changes, click on the icon in the upper right corner of the window.

Saving the configuration as the default for the selected pairing round

The application allows you to save the current configuration as default for the selected pairing round (TXM event). When the application is opened, the default configuration is displayed.

Only users with the **editor** and **administrator** roles can set the default configuration. Users with **viewer** permissions cannot change the configuration, they just see the configuration that is set as default.

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1. Select the desired pairing round.

   See the chapter **Pairing overview** - Selecting individual pairing rounds.

2. Adjust the configuration as needed.

   See the Configuration chapter.

3. Press the **set configuration as default** button.

Pairing overview

View an overview of pairings.

Note: Users with the **editor** or **administrator** role can customize the pairing recalculation and display method.

See the Configuration chapter.

They can save the settings as default for each pairing round.

See **Configuration** - Save configuration as default for the selected pairing round.

The Transplant Matching application also allows you to switch to the view mode for patients who are enrolled in the current round of the living donor program, with the option of adding individual donor and recipient parameters.

See the chapters Viewing the Patient Summary, Editing Donor Record Parameters, and Editing Recipient Record Parameters.

The display application also provides a selection of individual pairing rounds.

For more information, see the chapter Selecting individual pairing rounds.

The Top Matchings overview is displayed immediately after logging into the **Transplant Matching** system.

See the section Login to the system.

If you get somewhere else while working with the application, click either the **MATCHINGS** option or the application logo in the application header to return to the overview.

The **Top Matchnigs** page title indicates how many of the top matchings of the total number of matchings are displayed on the page, or just how many top matchings are displayed on the page (in the case of the ILP solver).

In the left column on the **Top Matchings** page, the possible pairings are displayed in the individual sections according to the scores.

- **Pairing header data**:
  - Score - Total score for the matching found.
  - Rounds - Number of rounds in the pairing.
  - Transplants - Number of transplants in the pairing.
  - Country flag, X/Y - How many donors/recipients from the matching country are in the matching.

- **Transplant list:**
  - Donor - Recipient, country flags - The pair corresponds to one transplant.
  - Light gray color - This is a transplant with a compatible blood type.
  - Dark gray color - This is a transplant with an incompatible blood type.
  - Color differentiation on the right edge of the pairing - Color-coded score of the corresponding transplant.
  - Numbers with letters on the left (1B, 2B, ...) - The number corresponds to the round number in the pairing. The number may or may not be followed by a letter. The letter B indicates that the round contains a bridging donor, the letter N indicates that the round contains a non-directed donor. If no letter is given, the corresponding round is a cycle.

When you click on a transplant, a detailed view of the selected transplant will appear on the right side of the **Top Matchings** page.

Details on the pairing detail:

- SCORE - Overall transplant score. The field is underlined according to the size of the score. This is calculated using the scorer set in the current configuration.
- BLOOD TYPE - Blood type of the donor and recipient.

  - Acceptable - Acceptable blood types of the recipient. For a transplant to be possible, the blood type of the donor must be compatible with the blood type of the recipient or be on this list of **acceptable** blood types.
- A, B, DRB1, OTHER - Categories of antigens and antibodies.
- ANTIGENS - List of antigens,
- ANTIBODIES - List of antibodies.
- Colors:
  - Green - The given antigen has been found for both donor and recipient. The colour does not apply to antibodies.
  - Red - Immunopathological reaction of antigen and antibody that makes transplantation impossible.
  - Grey - No reaction between antigens or antibodies with antigens of the other patient was found.

A light grey background colour of the pair in the header of the transplantation table indicates a compatible blood group, a dark grey an incompatible one.

Note: If the patients' gender, height and weight parameters are set (see Donor and Recipient settings), they are also displayed here. The parameters note, number of previous transplants and waiting since (since when the patient is waiting for a transplant) are also displayed.

Hover over the antigen or antibody code to see more information.

Selecting individual pairing rounds

The application allows the selection of individual pairing rounds (TXM events).

Example: the last round took place in January. However, if you want, you can look at the results of the pairings from July, for example.

Select the desired pairing round in the **TXM Event** option in the application header.

Note: Older TXM events may have the label CLOSED next to them. This label indicates that the TXM event is already closed and cannot be edited.

Patient management

View patient overview

The app also provides a view of patients who are enrolled in the living donor program.

In the application header, click **PATIENTS**.

The Patients report is loaded.

The left column lists the patients who are registered for the TXM event.

An item in the list is either a donor/recipient pair that is enrolled in the program or just the donor (for bridging and non-directed donors).

Click on an item in the list to see a detailed view of the selected patient or donor pair in the right column.

Details on the pairing detail:

- SCORE - Overall transplant score. The field is underlined according to the size of the score. This is calculated using the scorer set during the last configuration.

  See the **Configuration** chapter.

- BLOOD TYPE - Blood type of the donor and recipient.
  - Acceptable - Acceptable blood types of the recipient. For a transplant to be possible, the blood type of the donor must be compatible with the blood type of the recipient or be on this list of **acceptable** blood types.
- A, B, DRB1, OTHER - Categories of antigens and antibodies.
- ANTIGENS - List of antigens,
- ANTIBODIES - List of antibodies.
- Colors:
  - Green - The given antigen has been found for both donor and recipient. The colour does not apply to antibodies.
  - Red - Immunopathological reaction of antigen and antibody that makes transplantation impossible. Gray - Reaction between antigen or antibody with antigens of the other patient not found.
  - Grey - No reaction between antigens or antibodies with antigens of the other patient was found.

A light grey background colour of the pair in the header of the transplantation table indicates a compatible blood group, a dark grey an incompatible one.

Note: If the patients' gender, height and weight parameters are set (see Donor and Recipient settings), they are also displayed here. The parameters note, number of previous transplants and waiting since (since when the patient is waiting for a transplant) are also displayed.

Hover over the antigen or antibody code to see more information.

The Donor Settings and **Recipient Settings** options are used to customize the donor and recipient parameters.

For more information, see the chapters **Patient Management** - **Edit Donor Record Parameters** and **Edit Recipient Record Parameters**.

The donor record can also be deactivated or cancelled.

For more information, see the chapters **Patient management** - **Deactivating a patient record** and **Deleting a patient record**.

Edit donor record parameters

The application allows individual adjustment of donor parameters. The donor record can also be deactivated.

1. Open the **Patients** report.

   See the chapter **Patient Management** - **Viewing the Patient Overview**.
2. In the left column, click on the desired pair of patients or on the donor who does not have a recipient.
3. A detailed view of the patients is loaded on the right side of the page.
4. Click on the **Donor Settings** option.

Note: If this is a donor who does not have a recipient, click **Settings**.

5. The form for setting donor parameters will be displayed. Adjust the settings and values as needed.
   - **Active** switch - Activates or deactivates the donor and the corresponding recipient. The deactivated pair will not be included in the matching calculation.
   - **Blood group** - Set the blood group of the donor. Click to select the desired group.
   - **Antigens -** To add an additional antigen, enter the antigen code in the **Antigens** entry, confirm by pressing either the **`spacebar`** or **`enter`** key.

     Add any additional antigens in the same way.

     To remove an antigen from the list, click the icon next to the identifier of the desired antigen.
   - **Sex** - Setting the sex of the donor.
   - Other parameters - height in cm, weight in kg, year of birth.
   - **Note** - Option to provide more detailed information.

6. Save the parameters by pressing the **Save changes** button.

Edit recipient record parameters

The application allows individual adjustment of the recipient's parameters.

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1. Open the **Patients** report.

   See the chapter **Patient Management -** Viewing the Patient Overview.
2. Click on the desired pair of patients in the left column.
3. A detailed view of the patient pair is loaded on the right side of the page.
4. Click **Recipient Settings**.

5. The form for setting the recipient parameters is displayed. Adjust the settings and values as needed.
   - **Blood group** - Set the recipient's blood group. Click to select the appropriate group.
   - **Acceptable blood group** - Acceptable blood group of the recipient. For a transplant to be possible, the blood group of the donor must be compatible with the blood group of the recipient or be on this list of **acceptable** blood groups. Click to select the matching groups.
   - **Antigens** - To add an additional antigen, enter the antigen code in the **Antigens** entry, confirm by pressing either the **`spacebar`** or **`enter`** key.

     Add any additional antigens in the same way.

     To remove an antigen from the list, click the icon next to the identifier of the desired antigen.
   - **Antibodies** - To add an additional antibody, in the **Antibodies** section, under **ADD NEW RECIPIENT ANTIBODY,** click in the **Code** item its identifier and confirm by either pressing the **`space bar`** or **`enter`**. Set the *mean fluorescence intensity (MFI)*. Press the **Add +** key.

     Add any additional antibodies in the same way.

     To remove an antibody from the list, click the icon next to the desired antibody identifier.
   - **Antibodies cutoff** - The cut-off value common to all antibodies listed.

- **Sex** - Set the sex of the recipient.
- Other parameters - Height in cm, weight in kg, year of birth.
- **Note** - Option to provide more detailed information.
- **Waiting since** - The date from which the patient is recorded as a beneficiary. It is set using the calendar, which can be opened by clicking on the icon .
- **Previous transplants count** - Number of previous transplants.
- In the **Matching conditions** section, you can use the toggle switches to enable or disable the conditions for this recipient that are taken into account in the matching calculation.
  - **Require compatible blood group** - When enabled, a compatible blood group will be required for this recipient during pairing.
  - **Require new donor having better CI match than original donor** - When enabled, the CI match with the new donor will be required to be better than with the original donor.
  - **Require new donor having better CI match than original donor or blood group match** - When enabled, the CI match with the new donor will be required to be better than the original donor or the blood group match with the new donor.

6. Save the parameters by pressing the **Save changes** button.

Adding new patients

Registration of a new donor or donor-recipient pair.

Either in a pair with the recipient, or alone in the case of Bridging or Non-directed donors.

1. Open the **Patients** report.

See the chapter **Patient Management** - Viewing the Patient Overview.

2. Press the **add new +** button.
3. The modal window will display a form for adding new patients.

4. Enter the required data.

Entering donor data:

- **Select a country** - Click in the entry and select the appropriate country. Required.
- **Medical ID** - Enter the corresponding patient identifier. Required.
- **Type** - Enter the donor type. If you are recording a donor-recipient pair, leave the **Donor option checked**; if you are creating a donor record without matching the donor to a recipient, click the **Bridging Donor** or **Non-directed Donor** option. Required.
- **Antigens** - Enter the antigen codes sequentially in the **Antigens** entry, always confirming the entry by pressing either the `spacebar` or `enter` key. Required entry.
- **Blood group** - Click to select the corresponding blood group of the donor. Required.
- Click to set the patient's gender.
- Enter other values such as patient height in cm, patient weight in kg and year of birth.
- **Note** - Option to provide more detailed information.

Entering the recipient's details:

- **Select a country** - Click in the entry and select the appropriate country. Required.
- **Medical ID** - Enter the corresponding patient identifier. Required.
- **Blood group** - Set the recipient's blood group. Click to select the appropriate group. Required.

- **Acceptable blood group** - Acceptable blood group of the recipient. For a transplant to be possible, the blood type of the donor must be compatible with the blood type of the recipient or be on this list of acceptable blood types. Click to select the matching groups. Required.
- **Antigens** - Enter the antigen codes sequentially in the **Antigens** entry, always confirming the entry by pressing either the **`spacebar`** or **`enter`** key.
- **Antibodies** - Enter the individual antibodies of the recipient. To add an antibody, in the **Antibodies** section, in the **ADD NEW RECIPIENT ANTIBODY** box, click its identifier in **Code** and confirm by either pressing the **`spacebar`** or **`enter`**. Set the *mean fluorescence intensity (MFI)*. Press the **Add +** key.
- **Antibodies cutoff** - The cut-off value common to all antibodies listed. Required if antibodies are added.
- **Sex** - Set the sex of the recipient.
- Other parameters - Height in cm, weight in kg, year of birth.
- **Note** - Option to provide more detailed information.
- **Waiting since** - The date the recipient has been waiting for a transplant. It is set using the calendar, which can be opened by clicking on the icon .
- **Previous transplants count** - Number of previous transplants.

5. Press the **Save** button to save.

The record of the donor or donor-recipient pair is stored in the database.

Records can be edited,

See the chapters Modifying Donor Record Parameters and Modifying Recipient Record Parameters.

Deactivate patient record

Deactivation of the patient record.

After deactivation, the donor-recipient pair is not counted in the pairing.

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1. Open the relevant donor record for editing.

See the chapter Editing donor record parameters.

2. Turn off the **Active** switch.
3. Press the **Save changes** button.

In the patient list, the **INACTIVE** label appears next to the record with the deactivated pair**.**

The patient record can be reactivated by turning the **Active** switch back on.

Deleting a patient record

Remove a patient record from the database.

When deleted, the donor-recipient pair is removed from the database.

Please note: This step is irreversible.

1. Open the relevant donor record for editing.

   See the chapter Editing donor record parameters.
2. Press the **Delete** button.
3. Confirm the deletion of the donor-recipient pair record by pressing **OK**.

Generating a pairing report

The application allows you to generate a **Top Matchings** report into a PDF file.

The overview reflects the currently set configuration.

See also the Configuration chapter.

1. If you don't currently have the **Top Matchings** overview displayed, please display it.

   See the Pairing Overview chapter.
2. Click on the **Generate report** option in the header of the application.
3. In the **Generate report** modal window, set how much matching in addition to the selected matching should be exported and if patient information should also be exported. Press the **Export PDF** button to start the export. Conversely, to close the window without exporting, click the icon in the upper right corner of the window.

   Note: Higher number of matchings and export of patient section significantly increases the size of the generated file.
4. The application will generate a PDF report file and offer it to the browser resources for download.
5. Either save the file in the usual way, or open and print it if necessary.

The file has the mask **report_YYYY_MM_DD_hh_mm_ss** (YYYY - year, MM - month, DD - day, hh - hour, mm - minute, ss - second).

Patient summary export

The application allows you to export the patient summary to an XLSX file (MS Excel).

In the header of the application, click **Export patients**.

The application will offer the generated XLSX file to the browser to open or save.

The file has the mask **patients_YYYY_MM_DD_hh_mm_ss** (YYYY - year, MM - month, DD - day, hh - hour, mm - minute, ss - second).

Exiting the application and logging out of the system

1. Click the icon  in the app header.
2. Press the **Log out** button.

The user is logged out of the system and a login form is displayed, allowing the user to log back in or to log in another user.

 See also the chapter **Logging into the system**.

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