QUALITY EVALUATION OF BIOSIMILAR MEDICINES: AN OVERVIEW
Emrah KORKMAZ, Mehmet Emre ÖZDEMİRHAN, Evren ALGIN YAPAR
Department of Analysis and Control Laboratories, Turkish Medicines and Medical Devices Agency, 06430 Çankaya, Ankara, Turkey

ABSTRACT
Biosimilar medicines are biotherapeutics that are similar in quality, safety and efficacy to previously licensed reference biotherapeutics. The slightest change in any stage of production can cause differences in the product. Among the factors, affecting production can be listed as; host cell selection, fermenter type, ambient conditions, broth, substances used for cell culture, fermentation method and purification method. The similarity should be demonstrated by comparative quality, non-clinical and clinical tests. Research and development studies in the biopharmaceutical field bring diversity of quality control methods along with the formulation and manufacturing method of the biosimilars. Although there are some standardized and validated quality control methods given in the internationally recognized pharmacopoeias, there are many in house methods of biopharmaceutical product owners that can only be used as internal quality control methods by them. The main international sources for quality control methods of biopharmaceutics can be given as pharmacopoeias, International Organization for Standardization standards and Organization for Economic Co-operation and Development methods. In this review manufacturing process, regulatory guidelines and quality control of biosimilar medicines briefly are given.

Keywords: Biosimilars, biopharmaceutics, manufacturing, quality control, pharmacopoeial methods.

INTRODUCTION
Biosimilar medicines are biotherapeutics that are similar in quality, safety and efficacy to previously licensed reference biotherapeutics. Since the exact production method of the reference biological product is not known, different processes are mostly used in the production of biosimilar drugs. The slightest change in any stage of production can cause differences in the product. Among the factors, affecting production can be listed as; host cell selection, fermenter type, ambient conditions, broth, substances used for cell culture, fermentation method and purification method. Good Manufacturing Practices-GMP requirements for biological and biosimilar products are higher than for small molecules. The similarity should be demonstrated by comparative quality, non-clinical and clinical tests. While non-clinical tests can be grouped as physicochemical characterization, biological characterization, pre-clinical and pharmacokinetic-PK/pharmacodynamic-PD tests, clinical tests can be grouped as PK-PD tests, all reliability and effectiveness studies and clinical studies. Biosimilar products have high degree of similarity to the reference products, but they are not accepted as bioequivalent products. Research and development studies in the biopharmaceutical field bring diversity of quality control methods along with the formulation and manufacturing method of the biosimilars under the biological/biotechnological medicines. Although there are some standardized and validated quality control methods given in the internationally recognized pharmacopoeias, there are many in house methods of biopharmaceutical product owners that can only be used as internal quality control methods by them. The main international sources for quality control methods of biopharmaceutics can be given as pharmacopoeias, International Organization for Standardization standards and Organization for Economic Co-operation and Development methods. Between the pharmacopoeias European Pharmacopoeia, United States Pharmacopoeia, British Pharmacopoeia and Japanese Pharmacopoeia are mostly accepted ones. In the scope of above mentioned pharmacopoeias the analyses of biological and biotechnological medicines can be grouped as physical, chemical, pharmacological and microbiological controls. Those include identity, quantity and potency tests, thermostability, viral control tests, total and bound protein and purity (impurity) controls, sterility test, bacterial endotoxin and pyrogenicity test to prove...
their efficacy and safety. In this review, biosimilar medicines are briefly overviewed in the scope of regulations, manufacturing and quality control methods take place in the international standards such as pharmacopoeias.

**Regulatory Guidelines for Biosimilars**

Regulatory guidelines for biosimilars released by European Medicines Agency-EMA, U.S. Food And Drug Administration-FDA and World Health Organisation-WHO are listed below.

**European Medicines Agency**
- Guidelines on Similar Biological Medicinal Products
- Guideline on Similar Biological Medicinal Products Containing Biotechnology-Derived Proteins as Active Substance: Non-Clinical and Clinical Issues
- Guideline on Similar Biological Medicinal Products Containing Biotechnology-Derived Proteins as Active Substances: Quality Issues
- Questions and Answers on Biological Medicines (Similar Biological Medicinal Products).

**U.S. Food And Drug Administration**
- Guidance for Industry: Scientific Considerations in Demonstrating Biosimilarity to a Reference Product
- Guidance for Industry: Quality Considerations in Demonstrating Biosimilarity to a Reference Product
- Guidance for Industry: Clinical Pharmacology Data to Support a Demonstration of Biosimilarity to a Reference Product.

**World Health Organisation**
- Guidelines for Evaluation of Similar Biotherapeutic Products-SBP's.

**Manufacturing Process of Biosimilars**

Basic steps for manufacturing process of biosimilars are presented in Figure 1 and the critical factors for these steps are given below.

- **Cell Line**
- **Cell Volume Expansion**
- **Production Culture**
- **Centrifugation/Deep Filtration**
- **Chromatographic purification**
- **Virus filtration**
- **Concentration and formulation**

**Figure 1: Basic steps for manufacturing process of biosimilars.**

Critical factors that are effective on the success of the manufacturing steps are given below.

**Cell line selection**
- Mammalian
- Bacteria
- Yeast

**Cell culture process development**
- Oxygen levels
- Lactate production
- Temperature
- pH
- Osmolality
- Duration

**Purification process**
- Column chromatography
- Filtration
- Centrifugation

**Formulation**
- Buffer conditions
- pH
- Ionic strength
- Excipients amounts
- The final formulation (liquid, frozen liquid or lyophilisate)

**Quality Control of Biosimilars**

Under the class of biological and biotechnological medicines the biosimilars are analysed for below given tests and surveillance in terms to prove their quality.

**Characterization**

Characterization of biological and biotechnological medicines are evaluated according to the ICH Q6B guideline.

- **Physicochemical Properties**
  - Composition determination
  - Physical determination
  - Primarily Structure determination
  - Heterogeneity (activity, efficacy, safety)

- **Biological Activity**
  - Biological Assay (animal based, cell culture based, biochemical assay)
  - Potency

- **Immunological properties**
  - Affinity
  - Avidity
  - Immunoreactivity

- **Purity, impurity, and contaminants**

- **Quantity**

**Stability**

The effect of temperature, humidity, accelerated and stress conditions, light, container/closure system, stability after reconstitution of freeze-dried product variables on stability is evaluated in terms of the following parameters, which are indicated in the ICH Q5C guideline:

- Potency
- Purity and Molecular Characterisation
- Other Characteristics:
  - Visual appearance (colour and opacity for solutions/suspensions; colour, texture and dissolution time for powders).
  - Visible particulates (solutions or after the reconstitution of powders or lyophilised cakes)
  - pH,
  - Moisture level (powders and lyophilised products).
  - Sterility testing or alternatives (e.g., container/closure integrity testing)
  - Effect of additives (excipients, stabilisers, preservatives etc.) have to been evaluated.
  - Effect of container closure systems should be evaluated.
Comparability of biotechnological/biological products subject to changes in their manufacturing process are presented in ICH Q5E Guideline interms of non-clinical and clinical studies. Comparability Studies for Manufacturing Quality

Since the quality control of biopharmaceutical products has a great prospect in terms of the safe access to treatment that patients need the quality of them must comply with relevant internationally accepted criteria. Quality in biopharmaceutical products is a broad concept covering all aspects that affect the efficacy and safety of these products. All of the measures that require the assurance of biopharmaceutical quality constitute the quality assurance system. The Quality Assurance system consists of Quality Management-QM, Quality Assurance-QA and Good Manufacturing Practices-GMP and Quality Control-QC. As quality control and analysis of biopharmaceutical products are a part of GMP, quality control analyses should be carried out using validated methods appropriately to ensure the quality of the product. Biopharmaceutical products are subjected to quality control criteria and analysis within the scope of internationally accepted standards and guidelines specified or guided, including formulation, place and form of use. The quality control analyses made in biopharmaceutical products are mentioned below in the general framework within the scope of biopharmaceutical forms. Biological/biotechnological product analysis in pharmacopoeias can be grouped as below and can be given in detail in Table 1.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Tests</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>Calibrated pH meter</td>
</tr>
<tr>
<td>Identity and Heterogeneity</td>
<td></td>
</tr>
<tr>
<td>Dissolved molecule concentration</td>
<td>Osmolality</td>
</tr>
<tr>
<td>Charge paternity</td>
<td>Ion-Exchange Chromatography</td>
</tr>
<tr>
<td>Molecule weight</td>
<td></td>
</tr>
<tr>
<td>Primer structure</td>
<td></td>
</tr>
<tr>
<td>High level structure</td>
<td>Nuclear Magnetic Resonance-NMR, circular dichroism</td>
</tr>
<tr>
<td>Glycolysis heterogeneity</td>
<td>Gas Chromatography/monosaccharide structure analysis with Mass Spectrometry, oligosaccharide analysis</td>
</tr>
<tr>
<td>Amino terminal determination of protein</td>
<td>N terminal sequencing and HPLC</td>
</tr>
<tr>
<td>Carboxy terminal determination of protein</td>
<td>C-terminal sequencing with a combination of peptide mapping and electrospray ionization-mass spectrometry/mass spectrometry</td>
</tr>
<tr>
<td>Purity and Impurities</td>
<td></td>
</tr>
<tr>
<td>Fragments and isoforms</td>
<td>SDS-PAGE (reduced and non-reduced) HPLC, ultra-HPLC, liquid chromatography/mass spectrometry</td>
</tr>
<tr>
<td>Deamidation products</td>
<td>IEF, Ion exchange chromatography, peptide mapping</td>
</tr>
<tr>
<td>Dimers and large aggregates</td>
<td>Size exclusion chromatography, ultracentrifuge, SDS PAGE</td>
</tr>
<tr>
<td>Post-translational modifications</td>
<td>Peptide mapping, Liquid Chromatography-Electrospray Ionization/Mass Spectrometry</td>
</tr>
<tr>
<td>Host Cell proteins</td>
<td>SDS PAGE, immunological tests</td>
</tr>
<tr>
<td>Related proteins</td>
<td>SDS PAGE, immunological tests, HPLC, liquid chromatography/mass spectrometry</td>
</tr>
<tr>
<td>Production-based impurities</td>
<td>Gas chromatography/mass spectrometry</td>
</tr>
<tr>
<td>Potency</td>
<td>Validated biological potency tests</td>
</tr>
<tr>
<td>Quantity</td>
<td>Protein content</td>
</tr>
<tr>
<td></td>
<td>UV scanning</td>
</tr>
</tbody>
</table>

**Table 1: Pharmacopeial methods for quality control of biopharmaceuticals.**

**Comparability of biotechnological/biological products**

Comparability of biotechnological/biological products subject to changes in their manufacturing process are presented in ICH Q5E Guideline interms of non-clinical and clinical studies. Analyses made in biopharmaceutical products are continuously produced at the desired quality and meet the specified specifications to ensure effective and safe treatment. Therefore, all quality control analyses of the starting materials to the finished product are required as part of GMP. Which analyses are to be made for which biopharmaceutical product is...
determined according to the guidelines of the International Council for Harmonization of Technical Requirements for Pharmaceuticals for Human Use. With the developments in the pharmaceutical field, quality control tests will also diversify in parallel with newly developed innovative products and devices in addition to the mentioned analysis methods. For example; coulometric moisture determination with Karl Fischer method, particle size distribution and thermal analyses (Thermogravimetric Analysis-TGA, Differential Scanning Calorimetry-DSC) draws attention among the new tests that may be included in this variety.

CONCLUSION

Biosimilar products are gaining importance day by day, and there are many draft legislation and guidelines prepared by legal authorities for these products. In this direction, it will be useful to follow scientific and technological developments and current legislation during R&D, manufacturing and quality control stages.

REFERENCES

5. European Pharmacopoeia 10.0.