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GUIDELINES ON EVALUATION OF SIMILAR BIOTHERAPEUTIC PRODUCTS (SBPs)

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1 Introduction

Biotherapeutic products (biotherapeutics) have a successful record in treating many life-threatening and chronic diseases. However, their cost has often been high, thereby limiting their access to patients, particularly in developing countries. Recently, the expiration of patents and/or data protection for the first major group of originator's biotherapeutics has ushered in an era of products that are designed to be 'similar' to a licensed originator product. These products rely, in part, for their licensing on prior information regarding safety and efficacy obtained with the originator products. The clinical experience and established safety profile of the originator products should contribute to the development of similar biotherapeutic products (SBPs). A variety of terms, such as 'biosimilar products', 'follow-on protein products' and 'subsequent-entry biologics' have been coined by different jurisdictions to describe these products.

The term 'generic' medicine is used to describe chemical, small molecule medicinal products that are structurally and therapeutically equivalent to an originator product whose patent and/or data protection period has expired. The demonstration of bioequivalence of the generic medicine with a reference product is usually appropriate and sufficient to infer therapeutic equivalence between the generic medicine and the reference product. However, the approach established for generic medicines is not suitable for development, evaluation and licensing of SBPs since biotherapeutics consist of relatively large, and complex proteins that are difficult to characterize. The clinical performance of biotherapeutics can also be much influenced by the manufacturing process and some clinical studies will also be required to support the safety and efficacy of a SBP.

As part of its mandate for assuring global quality, safety and efficacy of biotherapeutics, the World Health Organization (WHO) provides globally accepted norms and standards for the evaluation of these products^{1,2}. Written standards established through the Expert Committee on Biological Standardization (ECBS) serve as a basis for setting national requirements for production, quality control and overall regulation of biological medicines. In addition, International Standards for measurement are essential tools for the establishment of potency for biological medicines worldwide³. Often they are used as primary standards for calibration of the secondary standards that are directly used in the biological assays.

An increasingly wide range of 'SBPs'¹ are under development or are already licensed in many countries and a need for guidelines for their evaluation and overall regulation was formally recognized by the WHO in 2007⁴. This document is intended to provide guidance for the development and evaluation of such biotherapeutics. However, the guidelines will serve as a living document that will be developed further in the line with the progress in scientific knowledge and experience.

It is essential that the standard of evidence supporting the decisions to license SBPs be sufficient to ensure that the product meets acceptable levels of quality, safety and efficacy to ensure public health. Also, it is expected that the elaboration of the data requirements and considerations for

¹ Not all products deemed to be 'SBPs' will be consistent with the definition and/or process for evaluation of SBPs as described in this guideline

the licensing of these products will facilitate development of and worldwide access to biotherapeutics of assured quality, safety and efficacy at more affordable prices. In most cases, their authorization will be evaluated on a case-by-case basis, and the amount of data required by a National Regulatory Authority (NRA) may vary. However, it is expected that a guideline on the scientific principles for evaluation of SBPs will help harmonize the requirements worldwide and will lead to greater ease and speed of approval and assurance of the quality, safety and efficacy of these products. It is important to note that biotherapeutics which are not shown to be similar to a RBP as indicated in this guideline should not be described as 'similar', nor called a 'SBP'. Such products could be licensed through the usual processes using a more extensive non-clinical and clinical data set or full licensing application.

It was recognized that a number of important issues associated with the use of SBPs need to be defined by the national authorities. They include but are not limited to the following:

- intellectual property issues;
- interchangeability and substitution of SBP with RBP; and
- labelling and prescribing information.

Therefore, the above mentioned issues are not elaborated in this document.

2 Aim

The intention of this document is to provide globally acceptable principles for licensing biotherapeutic products that are claimed to be similar to biotherapeutic products of assured quality, safety, and efficacy that have been licensed based on a full licensing dossier. On the basis of proven similarity, the licensing of a SBP will rely, in part, on non-clinical and clinical data generated with an already licensed reference biotherapeutic product (RBP). This guideline can be adopted as a whole, or partially, by NRAs worldwide or used as a basis for establishing national regulatory frameworks for licensure of these products.

3 Scope

This guideline applies to well-established and well-characterized biotherapeutic products such as recombinant DNA-derived therapeutic proteins.

Vaccines, plasma derived products, and their recombinant analogues are excluded from the scope of this document. WHO recommendations and regulatory guidance for these products are available elsewhere (<http://www.who.int/biologicals/areas/en/>).

4 Glossary

The definitions given below apply to the terms used in this guideline. They may have different meanings in other contexts.

Comparability exercise

Head-to-head comparison of a biotherapeutic product with a licensed originator product with the goal to establish similarity in quality, safety, and efficacy. Products should be compared in the same study using the same procedures.

Drug product

A pharmaceutical product type that contains a drug substance, generally in association with excipients.

Drug substance

The active pharmaceutical ingredient and associated molecules that may be subsequently formulated, with excipients, to produce the drug product. It may be composed of the desired product, product-related substances, and product- and process-related impurities. It may also contain other components such as buffers.

Equivalent

Equal or virtually identical in the parameter of interest. Equivalent efficacy of two medicinal products means they have similar (no better and no worse) efficacy and any observed differences are of no clinical relevance.

Generic medicine

A generic medicine contains the same active pharmaceutical ingredient as and is bioequivalent to an originator (comparator) medicine. Since generic medicines are identical in the active pharmaceutical substance, dose, strength, route of administration, safety, efficacy, and intended use, they can be substituted for the originator product.

Head-to-head comparison

Direct comparison of the properties of the SBP with the RBP in the same study.

Immunogenicity

The ability of a substance to trigger an immune response or reaction (*e.g.* development of specific antibodies, T cell response, allergic or anaphylactic reaction).

Impurity

Any component present in the drug substance or drug product that is not the desired product, a product-related substance, or excipient including buffer components. It may be either process- or product-related.

Non-inferior

Not clinically inferior to a comparator in the parameter studied. A non-inferiority clinical trial is one which has the primary objective of showing that the response to the investigational product is not clinically inferior to a comparator by a pre-specified margin.

Originator product

A medicine which has been licensed by the national regulatory authorities on the basis of a full registration dossier; *i.e.* the approved indication(s) for use were granted on the basis of full quality, efficacy and safety data.

Pharmacovigilance

The science and activities relating to the detection, assessment, understanding and prevention of adverse effects or any other drug related problems.

Reference biotherapeutic product (RBP)

A reference biotherapeutic product is used as the comparator for head-to-head comparability studies with the similar biotherapeutic product in order to show similarity in terms of quality, safety and efficacy. Only an originator product that was licensed on the basis of a full registration dossier can serve as a RBP. It does not refer to measurement standards such as international, pharmacopoeial, or national standards or reference standards.

Similarity

Absence of a relevant difference in the parameter of interest.

Similar biotherapeutic product (SBP)

A biotherapeutic product which is similar in terms of quality, safety and efficacy to an already licensed reference biotherapeutic product.

Well-established biotherapeutic product

Well-established biotherapeutic product is the one that has been marketed for a suitable period of time with a proven quality, efficacy and safety.

5 Scientific considerations and concept for licensing SBPs

For the licensing of generic medicines, the regulatory framework is well-established in most countries. Demonstration of structural sameness and bioequivalence of the generic medicine with the reference product is usually appropriate to infer (conclude) therapeutic equivalence between the generic and the reference product. However, the generic approach is not suitable for the licensing of SBPs since biotherapeutic products usually consist of relatively large and complex entities that are difficult to characterize. In addition, SBPs are manufactured and controlled according to their own development since the manufacturer of a SBP normally does not have access to all the necessary manufacturing information on the originator product. However, even minor differences in the manufacturing process may affect the pharmacokinetics, pharmacodynamics, efficacy and/or safety of biotherapeutic products. As a result, it has been agreed that the normal method for licensing generic medicines through bioequivalence studies alone is not scientifically appropriate for SBPs.

Decision making regarding the licensing of SBPs should be based on scientific evidence. The onus is on a manufacturer of a SBP to provide the necessary evidence to support all aspects of an application for licensing. As with any drug development program, the development of a SBP involves a stepwise approach starting with characterization and evaluation of quality attributes of the product and followed by non-clinical and clinical studies. Comprehensive characterization and comparison at the quality level are the basis for possible data reduction in the non-clinical and clinical development. If differences between the SBP and the RBP are found at any step, the underlying reasons for the differences should be investigated. Differences should always be explained and justified and may lead to the requirement of additional data (*e.g.* safety data).

In addition to the quality data, SBPs require non-clinical and clinical data generated with the product itself. The amount of non-clinical and clinical data considered necessary will depend on the product or class of products, the extent of characterization possible undertaken using state-of-the-art analytical methods, on observed or potential differences between the SBP and the RBP, and on the clinical experience with the product class (*e.g.* safety/immunogenicity concerns in a specific indication). A case by case approach is clearly needed for each class of products.

A SBP is intended to be similar to a licensed biotherapeutic product for which there is a substantial evidence of safety and efficacy. The ability for the SBP to be authorized based on reduced non-clinical and clinical data depends on proof of its similarity to an appropriate RBP through the comparability exercise. Manufacturers should demonstrate a full understanding of their product, consistent and robust manufacture of their product, and submit a full quality dossier that includes a complete characterization of the product. The comparability exercise between the SBP and the RBP in the quality part represents an additional element to the 'traditional' full quality dossier. The reduction in data requirements is therefore only possible for the non-clinical and/or clinical parts of the development program. The dosage form and route of administration of the SBP should be the same as for the RBP.

Studies must be comparative in nature employing analytical strategies (methods) that are sensitive to detect potential differences between the SBP and the RBP. The main clinical studies should use the final formulation derived from the final process material of the SBP. Otherwise,

additional evidence of comparability will be required to demonstrate that the SBP to be marketed is comparable to that used in the main clinical studies.

If similarity between the SBP and the RBP has been convincingly demonstrated, the SBP may be approved for use in other clinical indications of the RBP that have not directly been tested in clinical trials if appropriate scientific justification for such extrapolation is provided by the manufacturer (see section 10.7). Significant differences between the SBP and the chosen RBP detected during the comparability exercise would be an indication that the products are not similar and more extensive non-clinical and clinical data may be required to support the application for licensing.

Comparability exercise

The comparability exercise for a SBP is designed to show that the SBP has highly similar quality attributes when compared to the RBP. However, it also includes the non-clinical and clinical studies to provide an integrated set of comparative data. The comparability data at the level of quality can be considered to be an additional set of data over that which is normally required for an originator product developed as a new and independent product. This is the basis for reducing the non-clinical and clinical data requirements.

Although the quality comparisons are undertaken at various points throughout the quality application/dossier, a distinction should be made between usual quality data requirements and those presented as part of the comparability exercises. It may be useful to present these as a separate section in the quality module.

6 Key principles for the licensing of SBPs

- a. The development of a SBP involves stepwise comparability exercise(s) starting with comparison of the quality characteristics of the SBP and RBP. Demonstration of similarity of a SBP to a RBP in terms of quality is a prerequisite for the reduction of the non-clinical and clinical data set required for licensure. After each step of the comparability exercise, the decision to proceed further with the development of the SBP should be evaluated.
- b. The basis for licensing a product as a SBP depends on its demonstrated similarity to a suitable RBP in quality, non-clinical, and clinical parameters. The decision to license a product as a SBP should be based on evaluation of the whole data package for each of these parameters.
- c. If relevant differences are found in the quality, non-clinical, or clinical studies, the product will not likely qualify as a SBP and a more extensive non-clinical and clinical data set will likely be required to support its application for licensure. Such a products should not qualify as a SBP as defined in this guideline.

- d. If comparability exercises and/or studies with the RBP are not performed throughout the development process as outlined in this guidance document, the final product should not be referred to as a SBP.
- e. SBPs are not “generic medicines” and many characteristics associated with the authorization process-generally do not apply.
- f. SBPs, like other biotherapeutic products, require effective regulatory oversight for the management of their potential risks and in order to maximize their benefits.

7 Reference biotherapeutic product

Comprehensive information on the RBP provides the basis for establishing the safety, quality, and effectiveness profile to which the SBP is compared. The RBP also provides the basis for dose selection and route of administration, and is utilized in the comparability studies required to support the licensing application. The demonstration of an acceptable level of similarity between the SBP and RBP provides the rationale for utilizing a reduced non-clinical and clinical data set to support the application for market authorization of the SBP. Hence the RBP is central to the licensing of a SBP.

To support licensure of the SBP, similarity of the SBP to the RBP should be demonstrated through head-to-head comparisons with the RBP. The same RBP should be used throughout the entire comparability exercise.

The choice of a RBP is of critical importance for the evaluation of SBP. The rationale for the choice of the RBP should be provided by the manufacturer of the SBP in the submission to the NRA. Traditionally, NRAs have required the use of a nationally licensed reference product for licensing of generic medicines. This practice may not be feasible for countries lacking nationally-licensed RBPs. NRAs may need to consider establishing additional criteria to guide the acceptability of using a RBP licensed or resourced in other countries. The use of reference products with proven efficacy and safety in a given population will be one of the factors to consider. Another parameter may be market experience in addition to the duration and marketed use.

Considerations for choice of reference biotherapeutic product

Since the choice of a RBP is essential to the development of a SBP, the following should be considered.

- The RBP should have been marketed for a suitable duration and have a volume of marketed use such that the demonstration of similarity to it brings into relevance a substantial body of acceptable data regarding the safety and efficacy.
- The manufacturer needs to demonstrate that the chosen RBP is suitable to support the application for marketing authorization of a SBP.
- The RBP should be licensed based on a full quality, safety, and efficacy data. Therefore a SBP should not be considered as a choice for RBP.

- The same RBP should be used throughout the development of the SBP (*i.e.* for the comparative quality, non-clinical, and clinical studies).
- The drug substance of the RBP and the SBP must be shown to be similar.
- The dosage form and route of administration of the SBP should be the same as that of the RBP.
- The following factors should be considered in the choice of a RBP that is marketed in another jurisdiction.
 - The RBP should be licensed and widely marketed in another jurisdiction which has well-established regulatory framework and principles, as well as considerable experience of evaluation of biotherapeutic products, and post-marketing surveillance activities.
 - The acceptance of a RBP for evaluation of a SBP in a country does not imply approval for use of the RBP by the NRA of that country.

8 Quality

The quality comparison showing molecular similarity between the SBP and the RBP is indispensable to provide rationale for predicting that the clinical safety and efficacy profile of the RBP should also apply to the SBP so that the extent of the non-clinical and clinical data required with the SBP can be reduced. Ideally, development of a SBP involves thorough characterization of a number of representative lots of the RBP and then engineering a manufacturing process that will reproduce a product that is highly similar to the RBP in all clinically relevant product quality attributes; *i.e.* those product attributes that may impact clinical performance. A SBP is generally derived from a separate and independent master cell bank using independent manufacturing processes and control. These should be selected and designed to meet the required comparability criteria. A full quality dossier for both drug substance and drug product is always required, which complies with the standards as required by NRAs for originator products.

Increased knowledge of the relationship between biochemical, physicochemical, and biological properties of the product and clinical outcomes will facilitate development of a SBP. Due to the heterogeneous nature of proteins (especially those with extensive post-translational modifications such as glycoproteins), the limitations of some analytical techniques, and the generally unpredictable nature of the clinical consequences of minor differences in protein structural/ physico-chemical properties, the evaluation of comparability will have to be carried out independently for each product. For example, oxidation of certain methionine residues in one protein may have no impact on clinical activity whereas in another protein it may significantly decrease the intrinsic biological activity of the protein, or may increase its immunogenicity. Thus, differences in the levels of Met oxidation in the RBP and SBP would need to be evaluated and, if present, their clinical relevance would be evaluated and discussed.

To evaluate comparability, the manufacturer should carry out a comprehensive physicochemical and biological characterization of the SBP in head-to-head comparisons with the RBP. All aspects of product quality and heterogeneity should be assessed (see characterization below).

A high degree of similarity between the SBP and the RBP is the basis for reducing non-clinical and clinical requirements for licensing. However, some differences are likely to be found, *e.g.* due to differences in impurities or excipients. Such differences should be assessed for their potential impact on clinical safety and efficacy of the SBP and a justification, *e.g.* own study results or literature data, for allowing such differences provided. Differences of unknown clinical relevance, particularly regarding safety, may have to be addressed in additional studies pre- or post-marketing. Differences in quality attributes known to have potential impact on clinical activity will influence the judgment of consideration whether to name such product as 'SBP'. For example, if differences are found in glycosylation patterns that alter the biodistribution of the product and thereby change the dosing scheme, then this product can not be considered a SBP. Other differences between the SBP and RBP may be acceptable, and would not trigger the need for extra non-clinical and/or clinical evaluation. For example, a therapeutic protein that has lower levels of protein aggregates would, in most cases, be predicted to have a better safety profile than the RBP and would not need added clinical evaluation. Along the same lines, if heterogeneity in the terminal amino acids of the RBP is known, and sufficiently documented, without affecting the bioactivity, distribution, or immunogenicity of the RBP or similar products in its class, then there may be no need for added clinical safety or efficacy studies based upon this heterogeneity of the RBP and SBP.

Due to the unavailability of drug substance for the RBP, the SBP manufacturer will usually be using commercial drug product for the comparability exercise. The commercial drug product will, by definition, be in the final dosage form containing the drug substance(s) formulated with excipients. It should be verified that these do not interfere with analytical methods and thereby impact the test results. If the drug substance in the RBP needs to be purified from a formulated reference drug product in order to be suitable for characterization, studies must be carried out to demonstrate that product heterogeneity and relevant attributes of the active moiety are not affected by the isolation process. The approach employed to isolate and compare the SBP to the RBP should be justified and demonstrated, with data, to be appropriate for the intended purpose. Where possible, the product should be tested with and without manipulation.

8.1 Manufacturing process

Manufacture of a SBP should be based on a comprehensively designed production process taking all relevant guidelines into account. The manufacturer needs to demonstrate the consistency and robustness of the manufacturing process by implementing Good Manufacturing Practices⁵, modern quality control and assurance procedures, in-process controls, and process validation. The manufacturing process should meet the same standards as required by the NRA for originator products. The manufacturing process should be optimized to minimize differences between the SBP and RBP in order to (a) maximize the ability to reduce the clinical testing requirements for the SBP based upon the clinical history of the RBP, and (b) minimize any predictable impact on the clinical safety and efficacy of the product. Some differences between the SBP and RBP are expected and may be acceptable, provided, appropriate justification with regard to lack of impact on clinical performance is given.

It is understood that a manufacturer developing a SBP does not have access to confidential details of the manufacturing process of the RBP such that the process will differ from the licensed process for the RBP (unless there is a contractual arrangement with the manufacturer of the RBP). The manufacturing process for a SBP should employ state-of-the-art science and technology to achieve a high quality SBP that is as similar as possible to the RBP. This will involve evaluating the RBP extensively prior to developing the manufacturing process for the SBP. The SBP manufacturer should assemble all available knowledge of the RBP concerning the type of host cell, formulation and container closure system used for marketing the RBP. If applicable, the SBP manufacturer should then determine the potential impact of changing any one of these elements on product quality, safety and efficacy based on available evidence from public information, experience with previous use of the RBP. SBP manufacturer is encouraged to apply this knowledge to the design of the manufacturing process. The rationale for accepting these differences needs to be justified based upon sound science and clinical experience, either with the SBP, or the RBP.

As a general rule, the product should be expressed and produced in the same host cell type as the RBP (*e.g. E.coli, CHO cells, etc.*) in order to minimize the potential for important changes to critical quality attributes of the protein and to avoid introduction of certain types of process-related impurities (*e.g. host cell proteins, endotoxins, yeast mannans*) that could impact clinical outcomes and immunogenicity. The host cell type for manufacture of the SBP should only be changed if the manufacturer can demonstrate convincingly that the structure of the molecule is not affected or that the clinical profile of the product will not change. For example, somatropin produced in yeast cells appears to have similar characteristics to somatropin expressed in *E. coli*. In most cases, however, the use of a different host cell type will not be feasible for glycoproteins because glycosylation patterns vary significantly between different host cell types.

A complete description and data package should be provided that delineates the manufacturing process, starting with development of expression vectors and cell banks, cell culture/fermentation, harvest, purification and modification reactions, filling into bulk or final containers, and storage. The development studies conducted to establish and validate the dosage form, formulation, and container closure system (including integrity to prevent microbial contamination) and usage instructions should be also documented (see relevant guidelines such as ICH).

8.2 Characterization

Thorough characterization of both RBP and SBP should be carried out using appropriate, state-of-the-art biochemical, biophysical, and biological analytical techniques. For the active ingredient(s) (*i.e. the desired product*), details should be provided on primary and higher-order structure, post-translational modifications (including but not limited to glycoforms), biological activity, purity, impurities, product-related (active) substances (variants), and immunochemical properties, where relevant.

When conducting a comparability exercise, head-to-head characterization studies are required to compare the SBP and the RBP. The primary structure of SBP and the RBP should be identical.

If differences between the SBP and the RBP are found, their potential impact on safety and efficacy of the SBP should be evaluated. The predefined limits need to be considered in advance. The assessment of the results should include the investigation of the differences found between

SBP and RBP. This determination will be based upon knowledge of the relationship between product quality attributes and clinical activity of the RBP and related products, the clinical history of the RBP, and lot-to-lot differences for commercial lots of the RBP. For example, quality attributes such as composition and profile of glycosylation, biological activity which is known to be related to clinical activity, and receptor binding activity should be justified.

Knowledge of the analytical limitations of each technique used to characterize the product (*e.g.* limits of sensitivity, resolving power) should be applied when making a determination of similarity. Representative raw data should be provided for all complex analytical methods (*e.g.* high quality reproductions of gels, chromatograms, *etc.*) in addition to tabular data summarizing the complete data set and showing the results of all release and characterization analyses carried out on the SBP and the RBP.

The following criteria should be considered when conducting the comparability exercise:

8.2.1 Physicochemical Properties

The physicochemical characterization should include the determination of primary and higher order structure (secondary/tertiary/quaternary) using appropriate analytical methods (*e.g.* mass spectrometry, NMR) and other biophysical properties. An inherent degree of structural heterogeneity occurs in proteins due to the biosynthesis process such that the RBP and the SBP are likely to contain a mixture of post-translationally modified forms. Appropriate efforts should be made to investigate, identify and quantify these forms.

8.2.2 Biological Activity

Biological activity is the specific ability or capacity of the product to achieve a defined biological effect. It serves multiple purposes in the assessment of product quality and is required for characterization, and batch analysis. Ideally, the biological assay will reflect the understood mechanism of action of the protein and will thus serve as a link to clinical activity. A biological assay is a quality measure of the ‘function’ of the protein product and can be used to determine whether a product variant has the appropriate level of activity (*i.e.* a product-related substance) or is inactive (and is therefore defined as an impurity). The biological assay also complements the physicochemical analyses by confirming the correct higher order structure of the molecule. Thus, the use of a relevant biological assay(s) with appropriate precision and accuracy provides an important means of confirming that a significant functional difference does not exist between the SBP and the RBP.

For a product with multiple biological activities, manufacturers should perform, as part of product characterization, a set of relevant functional assays designed to evaluate the range of activities of the product. For example, certain proteins possess multiple functional domains that express enzymatic and receptor-binding activities. In such situations, manufacturers should evaluate and compare all relevant functional activities of the SBP and RBP.

Potency is the quantitative measure of the biological activity. A relevant, validated potency assay should be part of the specification for drug substance and/or drug product. The results of the potency assay should be provided and expressed in units of activity. Where possible (*e.g.* for *in vitro* biochemical assays such as enzyme assays or binding assays), the results may be expressed

as specific activities (*e.g.* units/mg protein). Assays should be calibrated against an international or national standard or reference reagent, when available and appropriate. WHO provides international standards and reference reagents, which serve as reference sources of defined biological activity expressed in an international unit or Unit. International standards and reference reagents are intended for calibration of national reference standards. (http://www.who.int/biologicals/reference_preparations/en/). Therefore, international or national standards and reference reagents should be used to determine the potency and to express results in IU or U. They are not intended for use as a RBP during the comparability exercise.

Biological assays can be used for other purposes than determination of potency. For example, a relevant biological assay is essential for determining whether antibodies that develop in response to the product have neutralizing activity that impacts the biological activity of the product and/or endogenous counterparts, if present (see section 10.6).

8.2.3 Immunochemical Properties

When immunochemical properties are part of the characterization (*e.g.* for antibodies or antibody-based products), the manufacturer should confirm that the SBP is comparable to the RBP in terms of specificity, affinity, binding kinetics, and Fc functional activity, where relevant.

8.2.4 Impurities

Due to the limited access to all necessary information on the manufacturing process as well as the drug substance of the originator product, it is recognized that the evaluation of similarity of the impurity profiles between SBP and RBP will be generally difficult. Nevertheless, process- and product-related impurities should be identified, quantified by state-of-the-art technology and compared between the SBP and RBP. Some differences may be expected because the proteins are produced by different manufacturing processes. If significant differences are observed in the impurity profile between the SBP and the RBP, their potential impact on efficacy and safety, including immunogenicity, should be evaluated. It is critical to have suitable assays for process-related impurities, specific to the cell line used for production.

8.3 Specifications

Specifications are employed to verify the routine quality of the drug substance and drug product rather than to fully characterize them. As for any biotherapeutic product, specifications for a SBP should be set as described in established guidelines and monographs, where these exist. It should be noted that pharmacopoeial monographs may only provide a minimum set of requirements for a particular product and additional test parameters may be required. Reference to analytical methods used and acceptance limits for each test parameter of the SBP should be provided and justified. All analytical methods referenced in the specification should be validated; the corresponding validation should be documented.

Specifications for a SBP will not be the same as for the RBP since the manufacturing processes will be different and different analytical procedures and laboratories will be used for the assays. Nonetheless, the specifications should capture and control important product quality attributes known for the RBP (*e.g.* correct identity; purity, potency; molecular heterogeneity in terms of

size, charge, and hydrophobicity, if relevant; degree of sialylation; number of individual polypeptide chains; glycosylation of a functional domain; aggregate levels; impurities such as host cell protein and DNA). The setting of specifications should be based upon the manufacturer's experience with the SBP (*e.g.* manufacturing history; assay capability; safety and efficacy profile of the product) and the experimental results obtained by testing and comparing the SBP and RBP. Sufficient lots of SBP should be employed in setting specifications. The manufacturer should demonstrate, whenever possible, that the limits set for a given specification are not significantly wider than the range of variability of the RBP over the shelf-life of the product, unless justified.

8.4 Analytical techniques

Although the power of analytical methods for characterization of proteins has increased dramatically over the past few decades, there are still obstacles to completely characterizing complex biotherapeutic products. A battery of state-of-the-art analyses is needed to determine structure, function, purity, and heterogeneity of the products. The methods employed should separate and analyze different variants of the product based upon different underlying chemical, physical, and biological properties of protein molecules. For example, PAGE, ion exchange chromatography, isoelectric focusing, and capillary electrophoresis all separate proteins based upon charge, but they do so under different conditions and based upon different physicochemical properties. As a result, one method may detect variants that another method does not detect. The goal of the comparability investigation is to be as comprehensive as possible in order to minimize the possibility of undetected differences between the RBP and SBP that may impact clinical activity. The analytical limitations of each technique (*e.g.* limits of sensitivity, resolving power) should be considered when making a determination of similarity between a SBP and a RBP.

The measurement of quality attributes in characterization studies (*versus* in the specifications) does not necessarily require the use of validated assays, but the assays should be scientifically sound and qualified; *i.e.* they should provide results that are meaningful and reliable. The methods used to measure quality attributes for lot release should be validated in accordance with relevant guidelines, as appropriate. A complete description of the analytical techniques employed for release and characterization of the product should be provided in the license application.

8.5 Stability

The stability studies should be in compliance with relevant guidance as recommended by the NRA. Studies should be carried out to show which release and characterization methods are stability-indicating for the product. Generally, stability studies should be summarized in an appropriate format such as tables, and they should include results from accelerated degradation studies and studies under various stress conditions (*e.g.* temperature, light, humidity, mechanical agitation). Accelerated stability studies comprise an important element of the determination of similarity between a SBP and a RBP because they can reveal otherwise-hidden properties of a product that warrant additional evaluation. They are also important for identifying the degradation pathways of a protein product. The results obtained from accelerated stability studies may show that additional controls should be employed in the manufacturing process and during shipping and storage of the product in order to ensure the integrity of the product. Head-to-head

accelerated stability studies comparing the SBP to the RBP will be of value in determining the similarity of the products by showing a comparable degradation profile. However, currently, stress testing carried out in a comparative manner does not provide an added value. Representative raw data showing the degradation profiles for the product should be provided in the license application. The stability data should support the conclusions regarding the recommended storage and shipping conditions and the shelf life/storage period for the drug substance, drug product, and process intermediates that may be stored for significant periods of time. Stability studies on drug substance should be carried out using containers and conditions that are representative of the actual storage containers and conditions. Stability studies on drug product should be carried out in the intended drug product container-closure system. Real time/real temperature stability studies will determine the licensed storage conditions and expiration dating for the product. This may or may not be the same as for the RBP.

9 Non-clinical evaluation

The non-clinical part of the guideline addresses the pharmaco-toxicological assessment of the SBP. The establishment of safety and efficacy of a SBP usually requires the generation of some non-clinical data with the SBP.

9.1 General considerations

The demonstration of a high degree of molecular similarity between the SBP and RBP should significantly reduce the need for non-clinical studies since the RBP will already have a significant clinical history. Non-clinical studies, should be conducted with the final formulation of the SBP intended for clinical use, unless otherwise justified.

The design of an appropriate non-clinical study program requires a clear understanding of the product characteristics. Results from the physico-chemical and biological characterization studies should be reviewed from the point-of-view of potential impact on efficacy and safety. When developing a SBP some existing guidelines may be relevant and should therefore be taken into account; *e.g.* the 'Note for preclinical safety evaluation of biotechnology-derived pharmaceuticals' (ICH S6)⁶.

SBPs often require the application of unique approaches to assessing their safety in non-clinical studies. Problems in the non-clinical evaluation of SBPs containing biotechnology-derived recombinant proteins as drug substance are often related to the fact that these products:

- may show species-specific pharmacodynamic activity such that it is sometimes difficult to identify a relevant species for pharmacodynamic and toxicological evaluation; and/or
- will, as 'foreign proteins', usually elicit an antibody response in long-term animal studies. Thus, the results of subchronic or chronic repeat dose studies may be difficult to interpret due to the formation of antibody complexes with the drug substance.

9.2 Special considerations

Non-clinical evaluation of a new biotherapeutic normally encompasses a broad spectrum of pharmacodynamic, pharmacokinetic and toxicological studies⁶. The amount of additional non-clinical data required to establish safety and efficacy of a SBP is considered to be highly dependent on the product and on substance-class related factors. Factors that often elicit the need for additional non-clinical studies include, but are not restricted to:

- Quality-related factors:

- Significant differences in the cell expression system compared with the RBP
- Significant differences in purification methods used
- The presence of a complex mixture of less well characterized product- and/or process-related impurities

- Factors related to pharmaco-toxicological properties of the drug substance:

- Mechanism(s) of drug action are unknown or poorly understood
- The drug substance is associated with significant toxicity and/or has a narrow therapeutic index
- Limited clinical experience with the RBP

Depending on these factors, the spectrum of studies required to establish safety and efficacy of the SBP may vary considerably and should be defined on a case-by-case basis. For example, in the case of a highly complex drug substance that is difficult to characterize by analytical techniques and which possesses a narrow therapeutic index, the non-clinical development program may encompass a significant portion of the spectrum of studies described in relevant guidelines such as ICH S6⁶. On the other hand, for products for which the drug substance and the impurity profile are well characterized by analytical means, which possess a wide therapeutic index and for which an extensive clinical experience is available, the non-clinical development program will likely be more limited. However, a head-to-head repeat dose toxicity study should usually constitute a minimum requirement for non-clinical evaluation of a SBP. The non-clinical studies constitute a part of the overall comparability exercise. Therefore, the studies should be comparative in nature and designed to detect differences in response between the SBP and the RBP and not just the response to the SBP alone. Any deviation to this approach should be appropriately justified.

In vitro studies:

Assays like receptor-binding studies or cell-based assays (*e.g.* cell-proliferation or cytotoxicity assays) should normally be undertaken in order to establish comparability of the biological/ pharmacodynamic activity of the SBP and RBP. Such data are usually already available from the

biological assays described in the quality part of the dossier (see chapter 8.2.2). Reference to these studies can be made in the non-clinical part of the dossier.

In vivo studies:

Animal studies should be designed to maximize the information obtained. Such studies should be comparative in nature (see above), should be performed in (a) species known to be relevant (*i.e.* a species in which the RBP has been shown to possess pharmacodynamic and/or toxicological activity) and employ state-of-the-art technology. Where the model allows, consideration should be given to monitoring a number of endpoints such as:

- Biological/ pharmacodynamic activity relevant to the clinical application. These data should usually be available from biological assays described in the quality part of the dossier (see chapter 8.2.2) and reference to these studies can be made in the non-clinical part of the dossier. If feasible, biological activity may be evaluated as part of the non-clinical repeat dose toxicity study (described below). *In vivo* evaluation of biological/ pharmacodynamic activity may be dispensable if *in vitro* assays are available, which have been validated to reliably reflect the clinically relevant pharmacodynamic activity of the RBP.
- Non-clinical toxicity as determined in at least one repeat dose toxicity study in a relevant species and including toxicokinetic measurements. These measurements should include determination and characterization of antibody responses, including anti-product antibody titres, cross reactivity with homologous endogenous proteins, and product neutralizing capacity. The duration of the studies should be sufficiently long to allow detection of potential differences in toxicity and antibody responses between the SBP and RBP.

Besides being a part of the overall comparability exercise, the comparative repeat dose toxicity study is considered to provide reassurance that no 'unexpected' toxicity will occur during clinical use of the SBP. If performed with the final formulation intended for clinical use, the repeat dose toxicity study will, in principle, allow for detection of potential toxicity associated with both the drug substance and product- and process-related impurities.

Although the predictive value of animal models for immunogenicity in humans is considered low, antibody measurements, if applicable, should be included in the repeat dose toxicity study to aid in the interpretation of the toxicokinetic data and to help assess, as part of the overall comparability exercise, whether important differences in structure or immunogenic impurities exist between the SBP and RBP (the immunological response may be sensitive to differences not detected by laboratory analytical procedures).

Depending on the route of administration, local tolerance may need to be evaluated. If feasible, this evaluation may be performed as part of the described repeat dose toxicity study.

On the basis of the demonstration of similarity between the SBP and RBP by the additional comparability exercise performed as part of the quality evaluation, normally other routine toxicological studies such as safety pharmacology, reproductive toxicology, genotoxicity and carcinogenicity studies are not generally requirements for the non-clinical testing of a SBP, unless triggered by results of the repeat dose toxicity study or the local tolerance study and/or by

other known toxicological properties of the RBP (*e.g.* known adverse effects of the RBP on reproductive function).

10 Clinical evaluation

The main/pivotal clinical data should be generated using the product derived from the final manufacturing process and therefore reflecting the product for which marketing authorization is being sought. Any deviation from this recommendation needs to be justified and additional data may be required, such as from PK bridging studies comparing the PK profiles of the products from the previous and final formulations. For changes in the manufacturing process ICH Q5E should be followed⁷.

Clinical studies should be designed to demonstrate comparable safety and efficacy of the SBP to the RBP and therefore need to employ testing strategies that are sensitive enough to detect relevant differences between the products, if present (see below).

The clinical comparability exercise is a stepwise procedure that should begin with pharmacokinetic and pharmacodynamic studies followed by the pivotal clinical trials. If at any step relevant differences between the SBP and the RBP are detected, the reasons need to be explored and justified. If this is not possible, the new product may not qualify as a SBP and a full licensing (stand alone) application should be considered.

10.1 Pharmacokinetic (PK) studies

The PK profile is an essential part of the basic description of a medicinal product and should always be investigated. PK studies should generally be performed for the routes of administration applied for and using doses within the therapeutic dose range recommended for the RBP.

PK studies must be comparative in nature and should be designed to enable detection of potential differences between the SBP and the chosen RBP. This is usually best achieved by performing single-dose, cross-over PK studies in a homogenous study population and by using a dose where the sensitivity to detect differences is largest. For example, for a medicinal product with saturable absorption (saturation kinetics), the lowest therapeutic dose would be most appropriate, provided that the employed assay can measure the resulting drug plasma levels with sufficient accuracy and precision. In order to reduce variability not related to differences between products, PK studies could be performed in healthy volunteers, if considered ethical and scientifically justified. If the investigated drug substance is known to have adverse effects and the pharmacological effects or risks are considered unacceptable for healthy volunteers, it may be necessary to perform the PK studies in the proposed patient population.

In general, single dose PK studies will suffice. However, in cases of dose or time-dependent pharmacokinetics, resulting in markedly higher concentrations at steady-state than expected from single dose data, a potential difference in the extent of absorption of the SBP and RBP may be larger at steady-state than after single dose administration. In such cases, it may be advisable for

the manufacturer to perform an additional comparative multiple dose study to ensure similar PK profiles also at steady-state before commencing the confirmatory clinical trial(s). In steady-state PK studies, the administration scheme should preferably use the highest customary dosage recommended for the RBP.

The choice of single-dose studies, steady-state studies, or repeated determination of PK parameters and the study population should be justified by the manufacturer. The cross-over design eliminates inter-subject variability and therefore, compared to the parallel design, reduces the sample size necessary to show equivalent PK profiles of the SBP and RBP. The treatment phases should be separated by an adequate wash-out phase to avoid carry-over effects. The cross-over design may not be appropriate for biological medicinal products with a long half-life or for proteins for which formation of anti-product antibodies is likely. In parallel designs, care should be taken to avoid relevant imbalances in all prognostic variables between treatment groups that may affect the pharmacokinetics of the drug substance (*e.g.* ethnic origin, smoking status, extensive/ poor metabolizer status of the study population).

PK comparison of the SBP and the RBP should not only include absorption/ bioavailability but should also include elimination characteristics; *i.e.* clearance and/or elimination half-life, since differences in elimination rate of the SBP and the RBP may exist.

Acceptance criteria for the demonstration of similar PK between the SBP and the RBP should be pre-defined and appropriately justified. It is noted that the criteria used in standard clinical PK comparability studies (bioequivalence studies) were developed for chemically-derived, orally administered products and may not necessarily be applicable for biological medicinal products. Due to the lack of established acceptance criteria designed for biologicals, the traditional 80-125 % equivalence range is often used. However, if the 90% confidence intervals of the ratio of the population geometric means (test/ reference) for the main parameters under consideration (usually rate and extent of absorption) fall outside this traditional range, the SBP may still be considered similar to the RBP provided there is sufficient evidence for similarity from the quality, non-clinical, PD, efficacy and safety comparisons.

Other PK studies, such as interaction studies (with drugs likely to be used concomitantly) or studies in special populations (*e.g.* children, the elderly and patients with renal or hepatic insufficiency) are not usually required for a SBP.

Historically, the PK evaluation of peptide or protein products has suffered from limitations in the assay methodology thus limiting the usefulness of such studies. Special emphasis should therefore be given to the analytical method selected and its capability to detect and follow the time course of the protein (the parent molecule and/or degradation products) in a complex biological matrix that contains many other proteins. The method should be optimized to have satisfactory specificity, sensitivity and a range of quantification with adequate accuracy and precision.

In some cases, the presence of measurable concentrations of endogenous protein may substantially affect the measurement of the concentration-time profile of the administered exogenous protein. In such cases, the manufacturer should describe and justify the approach to minimize the influence of the endogenous protein on the results.

10.2 Pharmacodynamic (PD) studies

Although comparative clinical trials are usually required for demonstration of similar efficacy and safety of the SBP and RBP, it may be advisable for the manufacturer to ensure similar PD profiles before proceeding to clinical trials, particularly if a difference in PK profiles of unknown clinical relevance has been detected.

In many cases, PD parameters are investigated in the context of combined PK/PD studies. Such studies may provide useful information on the relationship between dose/exposure and effect, particularly if performed at different dose levels. In the comparative PD studies, PD effects should be investigated in a suitable population using a dose/doses within the steep part of the dose-response curve in order to best detect potential differences between the SBP and the RBP. PD markers should be selected based on their clinical relevance.

10.3 Confirmatory pharmacokinetic/pharmacodynamic (PK/PD) studies

Usually, clinical trials are required to demonstrate similar efficacy between the SBP and the RBP. In certain cases, however, comparative PK/PD studies may be appropriate, provided that 1) the PK and PD properties of the RBP are well characterized, 2) at least one PD marker is a marker linked to efficacy (*e.g.* an accepted surrogate marker for efficacy), and 3) the relationship between dose/exposure, the relevant PD marker(s) and response/efficacy of the RBP is established. Euglycaemic clamp studies would be an example for acceptable confirmatory PK/PD studies for the comparison of efficacy of two insulins. In addition, absolute neutrophil count and CD34+ cell count are the relevant PD markers for the activity of granulocyte colony stimulating factor (G-CSF) and could be used in PK/PD studies in healthy volunteers to demonstrate similar efficacy of two G-CSF-containing medicinal products.

The study population and dosage should represent a test system that is known to be sensitive to detect potential differences between the SBP and the RBP. For example, in the case of insulin, the study population should consist of non-obese healthy volunteers or patients with type 1 diabetes rather than insulin-resistant obese patients with type 2 diabetes. Otherwise, it will be necessary to investigate a relevant dose range to demonstrate that the test system is discriminatory⁸. In addition, the acceptance ranges for demonstration of similarity in confirmatory PK and PD parameters should be pre-defined and appropriately justified. If appropriately designed and performed such PK/PD studies are often more sensitive to detect potential differences in efficacy than trials using clinical endpoints.

10.4 Efficacy studies

Dose finding studies are not required for a SBP. Demonstration of comparable potency, PK and PD profiles provide the basis for the use of the posology of the RBP in the confirmatory clinical trial(s).

Similar efficacy of the SBP and the chosen RBP will usually have to be demonstrated in adequately powered, randomized, and controlled clinical trial(s). The principles of such trials are laid down in relevant ICH guidelines^{8,9}. Clinical studies should preferably be double-blind or at a

minimum observer-blind. In the absence of any blinding, careful justification will be required to prove that the trial results are free from significant bias.

Potential differences between the SBP and the RBP should be investigated in a sensitive and preferably well-established clinical model. For example, in the case of growth hormone (GH), treatment-naïve children with GH deficiency usually represent the most appropriate study population as opposed to children with non GH-deficient short stature that are usually less sensitive to the effects of GH. Although adult patients with GH deficiency could also be considered a “sensitive” population, the endpoint used to measure effects of GH treatment (*i.e.* body composition) is less sensitive than the one used in children (*i.e.* longitudinal growth) making an equivalence or non-inferiority margin more difficult to define.

In principle, equivalence designs (requiring lower and upper comparability margins) are clearly preferred for the comparison of efficacy and safety of the SBP with the RBP. Non-inferiority designs (requiring only one margin) may be considered if appropriately justified. While both of the designs can be used, their advantages and disadvantages should be well understood. The designs should be chosen regarding the possible advantages and disadvantages of each (see section "Advantages and disadvantages of equivalence/ non-inferiority designs for SBPs"). For statistical considerations see section “Statistical considerations for the design and analysis of equivalence/ non-inferiority trials for SBPs” below.

Equivalence/ non-inferiority margins have to be pre-specified and justified based on clinical relevance; *i.e.* the selected margin should represent the largest difference in efficacy that would not matter in clinical practice. Treatment differences within this margin would thus, by definition, be acceptable because they have no clinical relevance.

Similar efficacy implies that similar treatment effects can be achieved when using the same dosage(s); in the head-to-head comparative trial(s), the same dosage(s) should be used for both the SBP and RBP. In cases for which the medicinal product is titrated according to treatment response (*e.g.* epoetin, insulin) rather than given at a fixed dosage (*e.g.* somatropin in GH-deficient children), equivalence/ non-inferiority should be demonstrated not only with regard to treatment response but also with regard to dosage. This is best achieved by defining co-primary endpoints that also include dosage.

Generally, equivalence trials are clearly preferable to ensure that the SBP is not clinically less or more effective than the RBP when used at the same dosage(s). For medicinal products with a wide safety margin, non-inferiority trials may also be acceptable. It should, however, be considered that non-inferior efficacy, by definition, does not exclude the possibility of superior efficacy of the SBP compared to the RBP which, if clinically relevant, would contradict the principle of similarity.

Therefore, prior to initiating the confirmatory clinical trial, all comparative data generated between the SBP and RBP up to this point should be carefully reviewed and analysed to ascertain similarity of the SBP and the RBP. The confirmatory trial marks the last step of the comparability exercise and prior demonstration of similar physicochemical characteristics, potency and PK/PD profiles make superior efficacy of the SBP compared to the RBP highly unlikely. However, in the rare event that, after completion of the study, the results would indeed indicate statistically superior efficacy it should be excluded that this superiority is clinically

meaningful and could be associated with increased adverse events if the SBP is prescribed at the same dosage as the RBP. In the case of an equivalence trial clinically meaningful differences, including superior efficacy, between the SBP and the RBP are excluded if the 95% confidence interval of the treatment difference is fully contained within the pre-specified two-sided (upper and lower) comparability margins. In the case of a non-inferiority trial, a post-hoc justification that superior efficacy, if observed, is not clinically meaningful may be more difficult.

Whatever the pre-defined study design, the real results obtained from the clinical trial(s) will determine whether the SBP and the RBP can be considered clinically similar. If clinically relevant differences are found, the new product should not be considered similar to the RBP and should be developed as a stand alone product.

Whereas several examples exist for licensing of SBPs based on equivalence trials (*e.g.* recombinant human GH, epoetin and G-CSF in the EU), experience with non-inferiority trials for this purpose is limited and mainly based on theoretical considerations. An additional advantage of demonstration of equivalent efficacy (rather than non-inferior efficacy) is that this would provide a stronger rationale for the possibility of extrapolation of efficacy data to other indications of the RBP, particularly if these include different dosages than the one(s) tested in the clinical trial (see section 10.7).

Advantages and disadvantages of equivalence/ non-inferiority designs for SBPs

An equivalence trial is designed to confirm the absence of a clinically meaningful difference between the SBP and the RBP. This is the most suitable design for confirming that SBP is equivalent to the RBP which is in line with the principle of similarity since a non-inferiority trial does not exclude the possibility that the SBP is shown to be statistically and clinically superior to the RBP which contradicts the principle of similarity. The following table highlights the advantages and disadvantages of each design.

Design	Advantages	Disadvantages
Equivalence	<p>Demonstration of equivalence provides a strong rationale for the possibility of extrapolation of efficacy to other indications of the RBP</p> <p>Current experience for the licensing of SBPs is based on equivalence trials</p>	<p>An equivalence trial tends to need a larger sample size to achieve the same study power as a non-inferiority trial</p> <p>A finding of superiority would lead to the failure of the equivalence trial. There would be no option to show that the superiority observed is not clinically relevant. However, a stand alone application might still be an option subject to a requirement for additional studies</p>

Non-inferiority	A non-inferiority trial requires a smaller sample size to achieve the same study power as an equivalence trial.	Post-hoc justification that a finding of statistically superior efficacy is not clinically relevant is difficult. If the superiority observed is considered clinically relevant, then the SBP would not be considered similar to the RBP and should be developed as a stand alone product.
	A finding of superiority of the SBP compared to the RBP would not lead to failure of a non-inferiority trial, provided it can be demonstrated that the superiority observed is not clinically relevant.	Demonstration that superior efficacy of the SBP is not associated with increased adverse events if the SBP is prescribed at the same dosage as the RBP would be required in all cases.
		Demonstration of non-inferiority does not provide a strong rationale for the possibility of extrapolation to other indications of the RBP.
		There is currently no experience with licensing of SBPs based on non-inferiority trials.

Statistical considerations for the design and analysis of equivalence/ non-inferiority trials for SBPs

As indicated above, equivalence or non-inferiority studies may be acceptable for the comparison of efficacy and safety of the SBP with the RBP. The choice of the clinical trial design will depend on the product in question, its intended use, disease prevalence and the target population. The specific design selected for a particular study should be clearly stated in the trial protocol and justified. The statistical issues involved in designing, analysing and interpreting equivalence and non-inferiority trials are complex and often very subtle. This section is intended to emphasize the importance of the points that need to be considered in designing and analysing equivalence and non-inferiority trials and does not provide a comprehensive overview of all statistical considerations. In particular, a good understanding of statistical confidence intervals and their application to equivalence and non-inferiority clinical trials is essential.

Irrespective of the trial design selected, a comparability margin should be specified during trial design and clearly documented in the study protocol. For an equivalence trial, both the lower and upper equivalence margins are required, while only one margin is required for a non-inferiority trial. The selection of the margin should be given careful consideration and should be justified both statistically and clinically. Adequate evidence of the effect size of the RBP should be provided to support the proposed margin. The magnitude and variability of the effect size of the RBP derived from historical trials should also be taken into consideration in determining the

comparability margin both in terms of the endpoint chosen and the population to be studied. It must be reasonably assured that if a difference between the RBP and SBP exists, then the study is capable of showing that difference (this is referred to as “assay sensitivity”).

Statistical analysis for both equivalence and non-inferiority designs is generally based on the use of two sided confidence intervals (typically at the 95% level) for the difference between treatments. For equivalence trials, equivalence is demonstrated when the entire confidence interval falls within the lower and upper equivalence margins. Non-inferiority evaluations are one sided and statistical inference is based only on the lower or upper confidence limit, whichever is appropriate for a given study. For example, if a lower margin is defined, non-inferiority is demonstrated when the lower limit of the confidence interval is above the non-inferiority margin. Analysis of non-inferiority trials can also be based on a one-sided confidence interval at the 97.5% level.

Details of the sample size calculations should be provided in the study protocol. The basis of estimates of any quantities used in the sample size calculation should also be clearly explained, and these estimates will usually be based on results from earlier trials with the RBP or published literature. Since the formulae for sample size calculations are slightly different between equivalence and non-inferiority trials, and the two sided equivalence trial tends to need a larger sample size than a one sided non-inferiority trial, sample size calculations should be based on methods specifically designed for equivalence or non-inferiority trials. When estimating the sample size for equivalence or non-inferiority trials it is usually assumed that there is no difference between SBP and RBP. An equivalence trial could be underpowered if the true difference is not zero. Similarly, a non-inferiority trial could be underpowered if the SBP is actually less effective than the RBP. Determination of the appropriate sample size is dependent on various factors including: the type of primary endpoint (*e.g.* binary, quantitative, time-to-event *etc.*), the pre-defined comparability margin, the probability of a type I error (falsely rejecting the null hypothesis) and the probability of a type II error (erroneously failing to reject the null hypothesis). Keeping the probability of a type II error low will increase the ability of the study to show equivalence or non-inferiority of the SBP to the RBP. The expected rates of patient dropouts and withdrawals should also be taken into consideration in the determination of the sample size.

10.5 Safety

Pre-licensing safety data should be obtained in a sufficient number of patients to characterize the safety profile of the SBP. Depending on their size and duration, efficacy trials may be sufficient or may need to be extended to provide an adequate safety database. Comparison with the RBP should include type, frequency and severity of adverse events/reactions. For cases in which similar efficacy is demonstrated in confirmatory PK/PD studies but safety data relevant for the target population cannot be deduced from these studies, safety data in the target population are still needed. For example, for two soluble insulins, the euglycaemic clamp study is considered the most sensitive method to detect differences in efficacy. However, immunogenicity and local tolerance of subcutaneously administered SBP cannot be assessed in such a study and should therefore be evaluated in the target population.

Safety data should preferably be comparative. Comparison with an external control group is usually hampered by differences in the investigated patient population and concomitant therapy, observation period and/or reporting.

Safety data obtained from the clinical trials can be expected to mainly detect frequent and short-term adverse events/reactions. Such data are usually sufficient pre-licensing, but further close monitoring of clinical safety of the SBP is usually necessary in the post-marketing phase (see section 11).

10.6 Immunogenicity

Immunogenicity of biotherapeutic products should always be investigated pre-authorization. Even if efficacy and safety of a SBP and RBP have been shown to be similar, immunogenicity may still be different.

The immune response against a biotherapeutic is influenced by many factors such as the nature of the drug substance, product- and process-related impurities, excipients and stability of the product, route of administration, dosing regimen, and patient-, disease- and/or therapy-related factors¹⁰.

The consequences of unwanted immunogenicity may vary considerably, ranging from clinically irrelevant to serious and life-threatening. Although neutralizing antibodies directly alter the pharmacodynamic effect of a product (*i.e.* by directly blocking active site of the protein), binding antibodies often affect pharmacokinetics and thereby also influence pharmacodynamics. Thus, an altered effect of the product due to anti-product antibody formation might be a composite of pharmacokinetic, pharmacodynamic and safety effects.

Immunogenicity of a biotherapeutic should always be investigated in humans since animal data are usually not predictive of the immune response in humans. The frequency and type of antibodies induced as well as possible clinical consequences of the immune response should be compared for the SBP and the RBP. Comparison with an external control group is not considered appropriate because this is usually hampered by differences in the investigated patient population, observation period, sampling time points, assays employed, and interpretation of results.

Generally, the amount of immunogenicity data obtained from the comparative efficacy trial(s) (*i.e.* trials that are powered for their primary efficacy endpoint) will allow detection of a marked increase in immunogenicity of the SBP compared to the RBP and will be sufficient pre-licensing. Where clinically meaningful or even serious antibody development has been encountered with the RBP or the substance class but is too rare to be captured pre-licensing (*e.g.* cross-reacting neutralizing anti-epoetin antibodies causing pure red cell aplasia), a specific risk management plan (RMP) for the SBP may be necessary to assess this specific risk post-marketing (see section 11). In case similar efficacy is demonstrated in confirmatory PK/PD study(ies), immunogenicity data in the target population are still needed (see section 10.5). If the manufacturer intends to extrapolate efficacy and safety data to other approved indications of the RBP (see section 10.7), care should be taken to ensure that immunogenicity is investigated in the patient population that carries the highest risk of an immune response and immune-related adverse events.

The manufacturer will need to justify their antibody testing strategy including the selection, assessment, and characterization of assays, identification of appropriate sampling time points including baseline, sample volumes and sample processing/storage as well as selection of statistical methods for analysis of data. Antibody assays need to be validated for their intended purpose. A screening assay of sufficient sensitivity should be used for antibody detection and a neutralization assay should be available for further characterization of antibodies, if present. Possible interference of the circulating antigen with the antibody assay(s) should be taken into account. Detected antibodies need to be further characterized and their potential clinical implications regarding safety, efficacy and pharmacokinetics evaluated. For example, the isotype of the antibodies should be determined if they may be predictive of safety (*e.g.* development of IgE antibodies correlates with the development of allergic and anaphylactic responses). If the antibody incidence is higher with the use of the SBP compared to the RBP, the reason for the difference needs to be investigated. Special attention should be paid to the possibility that the immune response seriously affects the endogenous protein and its unique biological function.

The required observation period for immunogenicity testing will depend on the intended duration of therapy and the expected time of antibody development and should be justified by the manufacturer. In the case of chronic administration, one-year data will usually be appropriate pre-licensing to assess antibody incidence and possible clinical implications. This is, for example, the case for somatropin-containing products, where antibody development usually occurs within the first 6-9 months of treatment but potential effects on growth would only be seen thereafter. In some cases, shorter pre-licensing observation periods may be sufficient; *e.g.* for insulins, where most susceptible patients will develop antibodies within the first 6 months of treatment and clinical consequences, if any, would usually be observed around the same time as antibody development. If considered clinically relevant, development of antibody titers, their persistence over time, potential changes in the character of the antibody response and the possible clinical implications should be assessed pre- and post-marketing.

Since pre-licensing immunogenicity data are often limited, further characterization of the immunogenicity profile may be necessary post-marketing, particularly, if rare antibody-related serious adverse events may occur that are not likely to be detected in the pre-marketing phase.

10.7 Extrapolation of efficacy and safety data to other clinical indications

If similar efficacy and safety of the SBP and RBP have been demonstrated for a particular clinical indication, extrapolation of these data to other indications of the RBP (not studied in independent clinical studies with the SBP) may be possible if all of the following conditions are fulfilled:

- A sensitive clinical test model has been used that is able to detect potential differences between the SBP and the RBP;
- The clinically relevant mechanism of action and/or involved receptor(s) are the same; *e.g.* GH action in different conditions of short stature in children; erythropoiesis-stimulating action of epoetins in different conditions associated with anaemia or for the purpose of autologous blood donation. If the mechanism of action is different or not known a strong scientific rationale and additional data (*e.g.* “PD fingerprint”, additional clinical data) will be needed;

- Safety and immunogenicity of the SBP have been sufficiently characterized and there are no unique/additional safety issues expected for the extrapolated indication(s), for which clinical data on the SBP are not being provided; *e.g.* immunogenicity data in immunosuppressed patients would not allow extrapolation to an indication in healthy subjects or patients with autoimmune diseases while the reverse would be valid;
- If the efficacy trial used a non-inferiority study design and demonstrated acceptable safety and efficacy of the SBP compared to the RBP, the applicant should provide convincing arguments that this finding can be applied to the extrapolated indications; *e.g.* results from a non inferiority trial in an indication where a low dose is used may be difficult to extrapolate to an indication where a higher dose is used, from both efficacy and safety point of view.

If these prerequisites for extrapolation of efficacy and safety data of the SBP to other indication(s) of the RBP are not fulfilled, the manufacturer will need to submit own clinical data to support the desired indication(s).

If extrapolation of results from clinical studies for one indication to one or more different indications is intended, a detailed scientific discussion on the benefit/ risk of such a proposal should be provided based on the above criteria.

11 Pharmacovigilance

As for most biological medicines, data from pre-authorization clinical studies are usually too limited to identify all potential unwanted effects of a SBP. In particular, rare adverse events are unlikely to be encountered in the limited clinical trial populations being tested with the SBP. Therefore, further close monitoring of the clinical safety of these products in all approved indications and a continued benefit-risk assessment is necessary in the post-marketing phase.

The manufacturer should submit a safety specification and pharmacovigilance plan at the time of submission of the marketing authorization application. The principles of pharmacovigilance planning can be found in relevant guidelines such as ICH E2E¹¹. The safety specification should describe important identified or potential safety issues for the RBP, the substance class and/or any that are specific for the SBP. The pharmacovigilance plan should describe the planned post-marketing activities and methods based on the safety specification¹¹. In some cases, risk minimization measures such as educational material for patients and/or treating physicians may enhance the safe use of the SBP.

Any specific safety monitoring imposed on the RBP or product class should be incorporated into the pharmacovigilance plan for the SBP, unless a compelling justification can be provided to show that this is not necessary. Moreover, potential additional risks identified during the review of the data obtained with the SBP should be subject to further safety monitoring (*e.g.* increased immunogenicity that might result from a difference in the glycosylation profile).

Post-marketing safety reports should include all information on product tolerability received by the marketing authorization holder. The safety information must be evaluated in a scientific manner and should include evaluation of the frequency and causality of adverse events.

Manufacturers should ensure that, at the time of the marketing authorization, they have in place an appropriate pharmacovigilance system including the services of a qualified person responsible for monitoring pharmacovigilance and the necessary means for the notification of adverse reactions that occur in any of the countries where the product is marketed.

After the marketing authorization is granted, it is the responsibility of the NRA to closely monitor the compliance of manufacturers with their marketing commitments, where appropriate, and particularly with their pharmacovigilance obligations (as previously described).

In addition, as for all biotherapeutics, an adequate system is necessary to ensure specific identification of the SBPs (*i.e.* traceability). The NRA shall provide a legal framework for proper pharmacovigilance surveillance and ensure the ability to identify any biotherapeutics marketed in their territory which is the subject of adverse reaction reports. This implies that an adverse reaction report for any biotherapeutic should include, in addition to the International Nonproprietary Names (INN)¹², other important indicators such as proprietary (brand) name, manufacturer's name, lot number and country of origin.

12 Prescribing information and label

The SBP should be clearly identifiable by a unique brand name. Where an INN is defined, this should also be stated. WHO policy on INNs should be followed (<http://www.who.int/medicines/services/inn/innquidance/en/index.html>). Provision of the lot number is essential as this is an important part of production information and is critical for traceability in cases where problems with a product are encountered.

The prescribing information for the SBP should be as similar as possible to that of the RBP except for product-specific aspects, such as different excipient(s). This is particularly important for posology and safety-related information, including contraindications, warnings and adverse events. However, if the SBP has fewer indications than the RBP, the related text in various sections may be omitted unless it is considered important to inform doctors and patients about certain risks; *e.g.* because of potential off-label use. In such cases it should be clearly stated in the prescribing information that the SBP is not indicated for use in the specific indication(s) and the reasons why. The NRA may choose to mention the SBP nature of the product and the studies that have been performed with the SBP including the specific RBP in the product information and/or to include instructions for the prescribing physician on how to use SBP products.

13 Roles and responsibilities of NRAs

One of the responsibilities of a NRA is to set up appropriate regulatory oversight for the licensing and post-marketing surveillance of SBPs that are developed and/or authorized for use

in its area of jurisdiction. The experience and expertise of NRA in evaluating biotherapeutic products is a key prerequisite for appropriate regulatory oversight of these products. The NRA is responsible for determining a suitable regulatory framework for licensing SBPs. The NRA may choose to utilize or amend existing pathways or develop a new pathway for this purpose.

As development of biotherapeutic products is a rapidly evolving area, regular review of the NRAs for their licensing, the adequacy of the regulations for providing oversight, and the processes and policies that constitute the regulatory framework is an essential component of a well-functioning and up-to-date regulatory oversight for biotherapeutics.

A NRA may possess the regulatory authority for authorization of all new drugs and as such may not need to amend its regulations to authorize SBPs. However, the EU has specifically amended its regulations to provide an abbreviated regulatory pathway for SBPs (biosimilars)^{13,14,15,16}. This issue is subject of discussion in a number of other countries where development of SBPs is ongoing. For instance, Health Canada and Japan have recently developed their guidelines for manufacturers, and national guidelines are in development in some other countries. The historical perspective of US FDA on the assessment of follow-on protein products has also been published¹⁷. In most instances, NRAs will need to provide guidance to manufacturers on the information needed and regulatory requirements for the authorization of SBPs. A majority of countries will either be using their existing legislation and applicable regulations or they will amend or develop entirely novel frameworks for the authorization of SBPs. In some jurisdictions, regulations for licensing subsequent entry versions of biotherapeutic products are intricately linked with policies for innovation. Hence a NRA may need to coordinate with other stakeholders for consistency.

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