**Name of journal:** ***World Journal of*** ***Gastroenterology***

**ESPS Manuscript NO: 29937**

**Manuscript Type: MINIREVIEWS**

**Biosimilars in inflammatory bowel disease: A review of post-marketing experience**

Deiana S *et al.* Biosimilars in IBD: Post-marketing review

Simona Deiana, Tommaso Gabbani, Vito Annese

**Simona Deiana, Tommaso Gabbani, Vito Annese,** Division of Gastroenterology, AOU Careggi University Hospital, 50139 Firenze, Italy

**Author contributions:** Gabbani T performed literature research, wrote the first draft and reviewed the article; Deiana S collaborated to literature search and reviewed the article; Annese V designed and coordinated the review, and revised the final draft the manuscript.

**Conflict-of-interest** **statement:** No potential conflicts of interest relevant to this article were reported.

**Open-Access:** This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

**Manuscript source:** Invited manuscript

**Correspondence to: Vito Annese**, **MD,** Emergency Department**,** Division of Gastroenterology, AOU Careggi**,** Largo Brambilla 3, 50139 Firenze, Italy.annesev@aou-careggi.toscana.it

**Telephone**: +39-55-7946035

**Received:** August 30, 2016

**Peer-review started:** August 31, 2016

**First decision:** September 21, 2016

**Revised:** October 1, 2016

**Accepted:** December 21, 2016

**Article in press:**

**Published online:**

**Abstract**

Biologic compounds are obtained from living organisms or cell cultures by means of biotechnology methods. A similar biologic drug, commonly called biosimilar, is a product copied by a native approved biologic drug whose license has expired. Biosimilar drugs usually are marketed at a lower price and provide important financial savings for public healthcare systems. Some differences between biosimilars and original biologic drugs might exist but they are acceptable if they fall within defined “boundaries of tolerance”: differences in some features between the two molecules are considered important only if clinical relevant. Considering that the efficacy of the innovator biologic drug has already been established, the clinical studies required for approval of a biosimilar could be reduced compared with those required for the approval of the originator. In this review, real life data available in inflammatory bowel disease patients treated with biosimilars are reported, documenting in general satisfactory outcomes, sustained efficacy and no sign of increased immunogenicity, although, further controlled data are awaited.

**Key words:** Biologic drugs; CTP-13; Adalimumab biosimilar; Infliximab biosimilars; ZRC-3197

**© The Author(s) 2016.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Core-tip:** Some differences between biosimilars and original biologic drugs exist but they are acceptable if they fall within defined “boundaries of tolerance”: variations in some features of the two molecules are considered important only if clinical relevant. Several real-life clinical data are already available in inflammatory bowel disease patients treated with biosimilars with satisfactory outcomes, but further controlled trials are awaited.

Deiana S, Gabbani T, Annese V. Biosimilars in Inflammatory bowel disease: A review of post-marketing experience. *World J Gastroenterol* 2016; In press

**INTRODUCTION**

Crohn’s disease (CD) and Ulcerative Colitis (UC) are chronic immune-mediated inflammatory gastrointestinal disorders that lead to impaired quality of life, disease complications and frequent need of surgery and hospitalization[1,2]. They represent a global public health problem; more than 3.5 millions of people are affected in Europe alone with a direct healthcare cost of 4.6-5.6 billions of Euros/year[3]. The prevalence of IBD is expected to increase further due to the early age of onset, the lifelong course and no increased mortality, therefore an appropriate long-term control of the disease is mandatory considering its social and economic burden. The introduction of targeted biological therapies has significantly improved the outcomes of IBD patients.

Infliximab was the first biological therapy approved in IBD followed by other anti-TNFα drugs (Adalimumab, Certolizumab, Golimumab) and by anti-integrin antibodies (Natalizumab, Vedolizumab). Other agents are under investigations in IBD, as Ustekinumab and Tofacitinib[4].

In the therapeutic paradigm, biological therapy was generally considered as separated from “conventional” treatment strategy, which includes mesalazine, glucocorticoids and oral immunosuppressants. The reasons are mostly related to the unknown safety profile of the biologics when they were first approved and their high cost. However, this distinction is not justified yet, especially by considering the progress made in the field of biological therapy and the advent of biosimilar drugs.

In response to the high cost of reference biological drugs and with the recent or imminent patent expiry, interest in biosimilars has grown. Because of their lower cost, they lead to a significant cost savings for the health community, increased earlier access to biological therapy and may facilitate the efficient allocation of the always limited financial resources[5]; more patients in the world could access biological agents earlier with also the possibility to switch from costly originator versions to biosimilar alternatives[6]. Biosimilars are expected to save 11.8-33.4 billion Euros between 2007 and 2020 in the EU and 44.2 billion US dollars over the 10- year period between 2014 and 2024[7].

**BIOLOGICAL THERAPIES AND BIOSIMILARS**

Biological products (or biologics) are defined as active substances derived from living cells or organisms with the aid of biotechnology methods (recombinant DNA, controlled gene expression, antibody technologies)[8]. The relatively high price of biologic agents and their recent or impending patent expiration has led to development of similar versions of these drugs, called “biosimilar agents”. The World Health Organization defines a biosimilar as a “biotherapeutic product which is similar in terms of quality, safety and efficacy to an already licensed reference biotherapeutic product[9]. Indeed, post-translational modifications, in particular glycosilation, are specific to the individual production process; no two batches of a single biologic [either a reference product (RP) or a biosimilar] will ever be identical [10]. Those differences are acceptable if molecule falls within defined “boundaries of tolerance”: variations in some features of the two molecules are only considered important if they are clinical relevant[11,12]. This principle applies also to biosimilars and their differences from RP are not significant if there are no clinically meaningful differences between the two drugs in terms of safety, purity and potency [13]. Comprehensive comparability testing is required to prove biosimilarity and to show that any differences found are not clinically meaningful: biosimilars undergo a strict regulatory process that involves proving structural, functional and biological biosimilarity to the RP.

Considering that the efficacy of the original biologic drug has already been confirmed, the clinical studies required for the approval of a biosimilar could be significantly less compared with clinical trials required for the approval of the reference product. Moreover, developing a biosimilar give the opportunity to pharmaceutical companies to get the authorization for all indications held by the native biologic drug, the so-called “extrapolation”. Extrapolation of data from one indication to another is also a pivotal aspect of biosimilar development[14-16]. FDA, Health Canada and EMA in the past have usually allowed the medical companies to perform extrapolation for all indications, thanks to comparability exercises without real clinical data for all indications[15].

**INFLIXIMAB AND INFLIXIMAB BIOSIMILAR**

Several multicenter, randomized, double-blind clinical trials have established the efficacy and safety of the infliximab in the treatment of IBD [17-19]. The results of the ACCENT I study[20] laid the foundations for the management and dosage of infliximab in CD patients in clinical practice. The major experience with infliximab in UC is based on the pivotal ACT trials; ACT I and ACT II demonstrated that Infliximab is able to induce clinical remission, mucosal healing and steroid sparing in UC patients[21].

The CT-P13 (Remsima-Celltrion, Incheon, South Korea and Inflectra-Hospira, Lake Forest, IL, United States), which is the first biosimilar agent of Infliximab, has been approved for the therapy of IBD and other autoimmune diseases in India and South Korea during the year 2012[22]. Today more than 34000 patients in more than 40 countries worldwide have been treated with this drug[23]. Two pivotal trials conducted in rheumatologic diseases have demonstrated its efficacy and its safety. The first randomized, phase I, double-blind study was performed in patients with ankylosing spondylitis. In this study the CT-P13 pharmacokinetic was demonstrated to be similar to that of the original drug. Moreover, the two biosimilar drugs showed good performance in terms of efficacy and safety[24].

Subsequently a phase III, double-blind study was performed in 604 rheumatoid arthritis patients. Two groups of patients were randomized to receive CT-P13 or Infliximab, at the same dose of 3 mg/kg and both received also methotrexate. The two patient groups showed similar response rate, drug-related adverse events and development rate of anti-drug antibodies at the end of the study[25].

Regarding immunogenicity, it is well-known that is common to most biologics including Infliximab. It is associated with the loss of response, an increased rate of infusion reactions and other adverse events [26]. The degree of immunogenicity is not the same for all biologics and only minor differences in the formulation, purity or packaging of a biological drug can affects its immunogenicity profile. In both PLANETAS and PLANETRA[24,25] study, ADAs against CT-P13 and Infliximab were measured with similar findings for the two agents. During the extension phase, ADA incidence was comparable between maintenance and switches groups and did not increase significantly.

All these data further support the extrapolation of CT-P13 to all the indications for which IFX is approved. Although clinical efficacy has only been demonstrated in rheumatologic diseases, in September 2013 EMA approved the biosimilar of infliximab not only for treatment of rheumatoid arthritis, ankylosing spondylitis and psoriatic arthritis, but also for inflammatory bowel disease (IBD) in adults and children. Even if the number of IBD patients treated with CT-P13 is limited, clinical experience is growing and initial data are now available: some studies have been published as full articles and some additional studies have also been presented only in abstract form (Table 1).

**CT-P13 POST-MARKETING STUDIES IN ADULT IBD**

No randomized controlled trials are available on the use of CT-P13 in IBD. A randomized, double-blind, parallel group study, the NOR-SWITCH study [ClinicalTrials.gov identifier: NCT02148640] is currently being pursued in Norway. The purpose of this study is to assess the safety and efficacy of switching from infliximab to the biosimilar treatment Remsima in patients with rheumatoid arthritis, spondyloarthritis, psoriatic arthritis, ulcerative colitis, Crohn's disease and chronic plaque psoriasis. It was estimated to be completed in May 2016, but fully published data are not available yet. Another study, sponsored by Celltrion, has been designed to assess non-inferiority in efficacy and to assess overall safety of CT-P13 compared to infliximab in patients with active Crohn's disease up to week 54 [ClinicalTrials.gov Identifier: NCT02096861]. This study will also provide information about switching from infliximab to CT-P13 and from CT-P13 back to infliximab; the enrolment is closed with 214 patients included but no data are available yet.

An open-label, retrospective, multicenter study has evaluated the safety and the efficacy of CT-P13 (Remsima®) in patients with IBD in South Korea[27]. One hundred and seventy-three patients were included: 95 patients with moderate-to-severe CD and 78 patients with moderate-to-severe UC. Treatment-related adverse events occurred in 10% of patients and were mostly mild-moderate in severity. There were five serious treatment-related adverse events (two infusion-related reactions, two infections, one abdominal pain) and no cases of malignancy, pneumonia, or death. No significant differences were observed in treatment-emergent antibody response (TEAR) incidence between naïve patients and the switch group. No unexpected treatment-emergent adverse events were observed during the study. Although the study was not powered for efficacy, positive outcomes for response and remission were also reported in patients with CD, and UC. All data confirm that CT-P13 was well tolerated and efficacious in patients with IBD.

Another retrospective multicenter study from South Korea has evaluated CD and UC patients treated with IFX biosimilar (both infliximab-naïve patients and patients who switched to CT-P13 from its originator) by using CDAI and partial Mayo score [28]. The efﬁcacy of CT-P13 was maintained in 92.6% of patients with CD and in 66.7% of patients with UC after the switch from inﬂiximab to biosimilar drug. Only 2 CD patients and 1 UC patient stopped therapy after switch because of lack of efficacy. Regarding safety, no CD patients reported adverse event during CT-P13 therapy, while 6 UC patients (11.8%) experienced adverse events.

Moreover, an open-label case series has evaluated 17 IBD patients (8 CD and 9 UC) at a tertiary center in South Korea[29]. Nine patients (four UC and five CD) switched from IFX to CT-P13 during the remission period and among these, one patient lost effect and another discontinued CT-P13 due to arthralgia. No serious or unexpected ADRs were evident.

Unlike previous studies, which only evaluated the efficacy and safety of CT-P13, an Hungarian prospective, multicenter, observational study also examined the immunogenicity of treatment with CT-P13 in IBD[30]. 210 patients (126 CD and 84 UC) patients were included. Adverse events were reported in 17.1% of all patients. Infusion reactions occurred in 6.6% of patients and were significantly more common in those with previous IFX exposure; serious infectious adverse events occurred in 5.7% of all patients, resulting in one death. Therapeutic drug levels were monitored and anti-drug antibodies (ADAs) were measured. Patients exposed to previous infliximab treatment had significantly higher baseline ADA positivity as compared with naïve patients (CD patients *P* = 0.006, UC patients *P* = 0.02), while there was no significant difference in ADA positivity at Week 14 between patient groups when stratified according to previous infliximab exposure. Moreover, this study showed that patients with previous infliximab exposure had a tendency towards lower early mean trough levels of the drug, decreased response rates and were more likely to develop allergic reactions.

Another Hungarian observational, prospective study enrolled 39 IBD (18 CD and 21 UC) patients to evaluate efficacy, safety and immunogenicity of CT-P13[31]. At week 8 clinical response and remission was achieved in 37.5% and 50% of the patients with luminal CD, and in 20% and 66.7% of UC patients. The study reported a mild arthralgia and an anaphylactic reaction after the second infusion of CT-P13 in a patient with high ADA levels and previously treated with the originator IFX. One UC patient developed toxic megacolon and underwent to colectomy.

A prospective observational study performed in a single center in Norway has evaluated the efficacy, tolerability, and safety of CT-P13 in 78 patients with moderate to severe disease (46 CD, 32 UC)[32]. About 79% of CD patients and 56% of UC patients achieved remission at week 14. There were no unexpected adverse events reported during the study. Immunogenicity was seen in 8 patients (4 CD and 4 UC) and lead to discontinuation of treatment in seven patients.

A German single-center study has evaluated 33 IBD patients treated with CT-P13 biosimilar and 86 IBD patients who received the infliximab[33]. CT-P13 serum levels, IFX serum levels and anti-drug antibody serum levels were measured in both groups to uncover significant differences in anti-drug immunogenicity. In total the analysis revealed no significant differences in anti-drug immunogenicity in patients receiving CT-P13 and Infliximab, demonstrating the feasibility of drug monitoring in IBD patients treated with the biosimilar.

A recent study[34] demonstrated that anti-Infliximab antibodies in IBD patients recognize and functionally inhibit CT-P13 to a similar degree, suggesting similar immunogenicity profile. All 69 positive anti-Infliximab patients were cross-reactive to CT-P13. Titers of antibodies to infliximab and CT-P13 were strongly correlated (*r* values between 0.92 and 0.99, *P* < 0.001). Anti-Infliximab antibodies of IBD patients exerted similar functional inhibition on CT-P13 or Infliximab TNF-α binding capacity.

In conclusion, all published studies show no apparent differences between biosimilar infliximab and the originator. However, contrasting data have been reported in a study reported in abstract by Murphy *et al*[41] They showed a higher rate of surgery and inadequate disease control in patients treated with CT-P13 compared with those treated with infliximab. But, response and remission rates were not reported and no descriptions of baseline characteristics are available.

**CT-P13 POST-MARKETING STUDY IN PEDIATRIC IBD**

The effects of switching to CT-P13 from infliximab have been investigated in a small prospective observational study from Poland of 39 pediatric IBD patients (32 CD, 7 UC) [35]. In the CD subgroup, 22 (69%) patients were in clinical remission before switching. In the CD group 69% were in remission at the time of switching and 31% had mild to moderate disease activity. After two infusions with CT-P13 a significant reduction in pediatric CDAI (PCDAI) was seen. After a further mean follow-up of 8 months after switching, 88% of the patients were in clinical remission. One infusion reaction to infliximab biosimilar was observed in a CD patient, which led to treatment discontinuation. In general, adverse event incidence did not differ significantly before and after the switch from infliximab RP to CT-P13. Despite several limitations of this study, as the small sample size, the heterogeneity of time of switching during therapy and the great variation in length of the individual follow-up period, it demonstrates that switching from infliximab RMP to CT-P13 seems to be well tolerated in children with CD.

**ADALIMUMAB BIOSIMILARS**

The originator biologic Adalimumab (Humira) is a human recombinant monoclonal antibody. This IgG1 antibody binds to TNF-alpha, avoiding it to join with its specific receptors. As is largely known, TNF-alpha is an important activator of the inflammatory cascade and a modulator of apoptosis mechanisms. The originator drug (AbbVie’s Humira) adalimumab, was approved since 2002 in US and since 2003 in Europe. This drug has generated income for 12.5 billion of dollars worldwide in 2014, but at the end of 2016 the license will expire in the USA, while in Europe will expire in first half of 2018. Nowadays, Adalimumab is authorized for the therapy of Rheumatoid Arthritis, Ankylosing Spondylitis, Psoriatic Arthritis, Juvenile Idiopathic Arthritis, Psoriasis, Crohn’s disease, and Ulcerative Colitis.

At the end of 2014, the first Adalimumab biosimilar drug started to be commercialized in India. The Indian drug company Zydus Cadila Healtcare Ltd started to sell the adalimumab biosimilar drug, ZRC-3197, with the name of Exemptia, for the first time in the world[36]. Analytical techniques were behind demonstration of the biosimilarity of ZRC-3197 in comparison with the original adalimumab. Primary and secondary structures were showed to be identical to the originator product. Also, ZRC-3197 showed comparable level of heterogeneity and purity, when matched with originator adalimumab drug. Moreover, ZRC-3197 demonstrated similar key properties if compared with Humira, analyzed by with cell-based assay and plasma resonance techniques. ZRC-3197 showed a Tumor Necrosis Factor counteracting activity and a tie kinship for FcγRIIIa receptor comparable with Adalimumab originator[37]. Cadila Healthcare Ltd at the end of 2013, launched a randomized, parallel-group, active controller, phase III trial to evaluate efficacy, tolerability and safety of ZRC-3197 in comparison with Humira in Rheumatoid Arthritis patients. In this study, 120 patients affected by Rheumatoid Arthritis for at least six months and seropositive active illness, were enrolled. All patients were in treatment with Methotrexate, 10-25 mg/wk for a minimum of twelve weeks at a fixed dose in the last four weeks. Patients were randomized to the administration of Humira (AbbVie) 40mg or Exemptia (Zyndus) 40 mg every two weeks for three months by a subcutaneous route. The proportion of subjects with an ACR 20 response on day 84 was the primary endpoint. The secondary end-points were: modification of Disease Activity Score 28, proportion of subjects with an ACR 50 response, proportion of subjects with an ACR 70 response and comparison between the two groups of percentage of patients with antidrug antibodies[38]. By analyzing the data from this study, ZRC-3197 showed comparable degree of efficacy, safety, and tolerability if compared with the original drug Humira. However, complete data of this trial are not yet available. In any case, based on these data, Indian drugs authority gave the agreement for ZRC-3197 marketing. In European Union and United States this drug would not had the agreement for marketing because of a more strict regulatory process[39]. Post-marketing efficacy and safety data has not been showed[40].

**CONCLUSION**

Several clinical data are already available in IBD patients treated with IFX-biosimilar or who were switched from to CT-P13 with satisfactory outcomes, sustained efficacy and no sign of increased immunogenicity or any other safety concerns. However, further controlled data are needed, and additional studies that will support the validity of indication extrapolation to IBD are ongoing. No contraindication for switching from the originator to the relative biosimilar have been raised, however some gastroenterological and rheumatologic scientific associations have pointed out doubts about extrapolation technique of indication and its results. Realization of specific trials for each disease is desirable before biosimilar approval. Unfortunately, the increasingly number of treatment with biologics and their high cost, necessarily require a reduction of the price of these compounds to allow their sustainability by healthcare systems. More long term data on loss of response rates in switched therapies of IBD, as well as more data on drug levels and antibodies are awaited to assist physicians’ and patients’ confidence.

**REFERENCES**

1 **Solberg IC**, Lygren I, Jahnsen J, Aadland E, Høie O, Cvancarova M, Bernklev T, Henriksen M, Sauar J, Vatn MH, Moum B. Clinical course during the first 10 years of ulcerative colitis: results from a population-based inception cohort (IBSEN Study). *Scand J Gastroenterol* 2009; **44**: 431-440 [PMID: 19101844 DOI: 10.1080/00365520802600961]

2 **Solberg IC**, Vatn MH, Høie O, Stray N, Sauar J, Jahnsen J, Moum B, Lygren I. Clinical course in Crohn's disease: results of a Norwegian population-based ten-year follow-up study. *Clin Gastroenterol Hepatol* 2007; **5**: 1430-1438 [PMID: 18054751 DOI: 10.1016/j.cgh.2007.09.002]

3 **Burisch J**, Jess T, Martinato M, Lakatos PL. The burden of inflammatory bowel disease in Europe. *J Crohns Colitis* 2013; **7**: 322-337 [PMID: 23395397 DOI: 10.1016/j.crohns.2013.01.010]

4 **Pedersen J**, Coskun M, Soendergaard C, Salem M, Nielsen OH. Inflammatory pathways of importance for management of inflammatory bowel disease. *World J Gastroenterol* 2014; **20**: 64-77 [PMID: 24415859 DOI: 10.3748/wjg.v20.i1.64]

5 **Abraham J**. Developing oncology biosimilars: an essential approach for the future. *Semin Oncol* 2013; **40** Suppl 1: S5-24 [PMID: 24267944 DOI: 10.1053/j.seminoncol.2013.09.015]

6 **Brodszky V**, Baji P, Balogh O, Pentek M. Budget impact analysis of biosimilar infliximab (CT-P13) for the treatment of rheumatoid arthritis in six Central and Eastern European countries. *Eur J Health Econ* 2014; **15** (Suppl 1): 65-71 [DOI: 10.1007/s10198-014-0595-3]

7 **Haustein R,** Millas C, Hoer A, Haussler B. Saving money in the European healthcare systems with biosimilars. *Generics Biosimilars Initiat J* 2012; **1**: 120e6. [DOI: 10.5639/gabij.2012.0103-4.036]

8 **Annese V**, Vecchi M. Use of biosimilars in inflammatory bowel disease: Statements of the Italian Group for Inflammatory Bowel Disease. *Dig Liver Dis* 2014; **46**: 963-968 [PMID: 25139379 DOI: 10.1016/j.dld.2014.07.019]

9 **World Health Organization.** Expert Committee on Biological Standardization. Guidelines on evaluation of similar biotherapeutic products. 2009. Available at: http: //www.who.int/biologicals/areas/biological\_therapeutics/BIOTHERAPEUTICS\_FOR\_WEB\_22AP RIL2010.pdf [Accessed February 28, 2016].

10 **Al-Sabbagh A**, Olech E, McClellan JE, Kirchhoff CF. Development of biosimilars. *Semin Arthritis Rheum* 2016; In press [DOI: 10.1016/j.semarthrit.2016.01.002]

11 **United States Food and Drugs Administration.** Demonstration of comparability of human biological products, including therapeutic biotechnology-derived products. Available from: URL: http: //www.fda.gov/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm122879.htm

12 **International Conference on Harmonisation.** Q5E Comparability of biotechnological/biological products subject to changes in their manufacturing process. Available from: URL: http: //www.ich.org/fileadmin/Public\_Web\_Site/ICH\_Products/Guidelines/Quality/Q5E/Step4/Q5E\_Guideline.pdf

13 **United States Food and Drug Administration.** Scientific considerations in demonstrating biosimilarity to a reference product. Guidance for industry. April 2015. Available from: URL: http: //www.fda.gov/downloads/DrugsGuidanceComplianceRegulatoryInformation/Guidances/UCM

14 **Ebbers HC**. Biosimilars: in support of extrapolation of indications. *J Crohns Colitis* 2014; **8**: 431-435 [PMID: 24594005 DOI: 10.1016/j.crohns.2014.02.007]

15 **Feagan BG**, Choquette D, Ghosh S, Gladman DD, Ho V, Meibohm B, Zou G, Xu Z, Shankar G, Sealey DC, Russell AS. The challenge of indication extrapolation for infliximab biosimilars. *Biologicals* 2014; **42**: 177-183 [PMID: 24962198 DOI: 10.1016/j.biologicals.2014.05.005]

16 **Weise M**, Kurki P, Wolff-Holz E, Bielsky MC, Schneider CK. Biosimilars: the science of extrapolation. *Blood* 2014; **124**: 3191-3196 [PMID: 25298038 DOI: 10.1182/blood-2014-06-583617]

17 **Lémann M**, Mary JY, Duclos B, Veyrac M, Dupas JL, Delchier JC, Laharie D, Moreau J, Cadiot G, Picon L, Bourreille A, Sobahni I, Colombel JF. Infliximab plus azathioprine for steroid-dependent Crohn's disease patients: a randomized placebo-controlled trial. *Gastroenterology* 2006; **130**: 1054-1061 [PMID: 16618399 DOI: 10.1053/j.gastro.2006.02.014]

18 **Colombel J,** Sandborn W, Reinisch W, Mantzaris G, Kornbluth A, Rachmilewitz D, Lichtiger S, D'Haens G, Diamond RH, Broussard DL, Tang KL, van der Woude CJ, Rutgeerts P; SONIC Study Group. Infliximab, azathioprine, or combination therapy for Crohn's disease. *N Engl J Med* 2010; **362**: 1383–1395 [DOI: 10.1056/NEJMoa0904492]

19 **Panaccione R**, Ghosh S, Middleton S, Márquez JR, Scott BB, Flint L, van Hoogstraten HJ, Chen AC, Zheng H, Danese S, Rutgeerts P. Combination therapy with infliximab and azathioprine is superior to monotherapy with either agent in ulcerative colitis. *Gastroenterology* 2014; **146**: 392-400.e3 [PMID: 24512909 DOI: 10.1053/j.gastro.2013.10.052]

20 **Hanauer SB**, Feagan BG, Lichtenstein GR, Mayer LF, Schreiber S, Colombel JF, Rachmilewitz D, Wolf DC, Olson A, Bao W, Rutgeerts P. Maintenance infliximab for Crohn's disease: the ACCENT I randomised trial. *Lancet* 2002; **359**: 1541-1549 [PMID: 12047962 DOI: 10.1016/S0140-6736(02)08512-4]

21 **Rutgeerts P**, Sandborn WJ, Feagan BG, Reinisch W, Olson A, Johanns J, Travers S, Rachmilewitz D, Hanauer SB, Lichtenstein GR, de Villiers WJ, Present D, Sands BE, Colombel JF. Infliximab for induction and maintenance therapy for ulcerative colitis. *N Engl J Med* 2005; **353**: 2462-2476 [PMID: 16339095 DOI: 10.1056/NEJMoa050516]

22 **Evaluate™.** KFDA Approves Remsima(TM) (infliximab), the World's First Antibody Biosimilar [press release]. Celltrion, Johnson & Johnson; 2012 [July 23]. Available from: URL: http: //www.evaluategroup.com/Universal/View.aspx?type=Story&id=320129.

23 **Jahnsen J**. Clinical experience with infliximab biosimilar Remsima (CT-P13) in inflammatory bowel disease patients. *Therap Adv Gastroenterol* 2016; **9**: 322-329 [PMID: 27134662 DOI: 10.1177/1756283X16636764]

24 **Park W,** Hrycaj P, Jeka S, Kovalenko V, Lysenko G, Miranda P, Mikazane H, Gutierrez-Ure-a S, Lim M, Lee YA, Lee SJ, Kim H, Yoo DH, Braun J. A randomised, double-blind, multicentre, parallel-group, prospective study comparing the pharmacokinetics, safety,and efficacy of CT-P13 and innovator infliximab in patients with ankylosing spondylitis: the PLANETAS study. *Ann Rheum Dis* 2013; **72**: 1605–1612 [DOI: 10.1136/annrheumdis-2012-203091]

25 **Yoo DH**, Hrycaj P, Miranda P, Ramiterre E, Piotrowski M, Shevchuk S, Kovalenko V, Prodanovic N, Abello-Banfi M, Gutierrez-Ure-a S, Morales-Olazabal L,Tee M, Jimenez R, Zamani O, Lee SJ, Kim H, Park W, Müller-Ladner U. A randomised, double-blind, parallel-group study to demonstrate equivalence in efficacy and safety of CT-P13 compared with innovator infliximab when coadministered with methotrexate in patients with active rheumatoid arthritis: the PLANETRA study. *Ann Rheum Dis* 2013; **72**: 1613–1620 [DOI: 10.1136/annrheumdis-2012-203090]

26 **Allez M**, Karmiris K, Louis E, Van Assche G, Ben-Horin S, Klein A, Van der Woude J, Baert F, Eliakim R, Katsanos K, Brynskov J, Steinwurz F, Danese S,Vermeire S, Teillaud JL, Lémann M, Chowers Y. Report of the ECCO pathogenesis workshop on anti-TNF therapy failures in inflammatory bowel diseases: definitions, frequency and pharmacological aspects. *J Crohn's Colitis* 2010; **4**: 355–366 [DOI: 10.1016/j.crohns.2010.04.004]

27 **Park S,** Kim Y, Lee J, Kwon H, Lee S, Park D, Kim HK, Cheon JH, Im JP, Kim YS, Lee SY, Lee SJ. Post-marketing study of biosimilar infliximab (CT-P13) to evaluate its safety and efficacy in Korea. *Expert Rev Gastroenterol Hepatol* 2015; **9**: 35–44 [DOI: 10.1586/17474124.2015.1091309]

28 **Jung YS**, Park DI, Kim YH, Lee JH, Seo PJ, Cheon JH, Kang HW, Kim JW. Efficacy and safety of CT-P13, a biosimilar of infliximab, in patients with inflammatory bowel disease: A retrospective multicenter study. *J Gastroenterol Hepatol* 2015; **30**: 1705-1712 [PMID: 25974251 DOI: 10.1111/jgh.12997]

29 **Kang YS**, Moon HH, Lee SE, Lim YJ, Kang HW. Clinical Experience of the Use of CT-P13, a Biosimilar to Infliximab in Patients with Inflammatory Bowel Disease: A Case Series. *Dig Dis Sci* 2015; **60**: 951-956 [PMID: 25326115 DOI: 10.1007/s10620-014-3392-z]

30 **Gecse KB**, Lovász BD, Farkas K, Banai J, Bene L, Gasztonyi B, Golovics PA, Kristóf T, Lakatos L, Csontos ÁA, Juhász M, Nagy F, Palatka K, Papp M, Patai Á, Lakner L, Salamon Á, Szamosi T, Szepes Z, Tóth GT, Vincze Á, Szalay B, Molnár T, Lakatos PL. Efficacy and Safety of the Biosimilar Infliximab CT-P13 Treatment in Inflammatory Bowel Diseases: A Prospective, Multicentre, Nationwide Cohort. *J Crohns Colitis* 2016; **10**: 133-140 [PMID: 26661272 DOI: 10.1093/ecco-jcc/jjv220]

31 **Farkas K**, Rutka M, Bálint A, Nagy F, Bor R, Milassin Á, Szepes Z, Molnár T. Efficacy of the new infliximab biosimilar CT-P13 induction therapy in Crohn's disease and ulcerative colitis - experiences from a single center. *Expert Opin Biol Ther* 2015; **15**: 1257-1262 [PMID: 26134250 DOI: 10.1517/14712598.2015.1064893]

32 **Jahnsen J**, Detlie TE, Vatn S, Ricanek P. Biosimilar infliximab (CT-P13) in the treatment of inflammatory bowel disease: A Norwegian observational study. *Expert Rev Gastroenterol Hepatol* 2015; **9** Suppl 1: 45-52 [PMID: 26395534 DOI: 10.1586/17474124.2015.1091308]

33 **Schulze K**, Koppka N, Lutter F, Brandhorst G, Schreiber S, Helwig U. CT-P13 (Inflectra™, Remsima™) monitoring in patients with inflammatory bowel disease. *Biologicals* 2016; **44**: 463-466 [PMID: 27435444 DOI: 10.1016/j.biologicals.2016.06.011]

34 **Ben-Horin S,** Yavzori M, Benhar I, Fudim E, Picard O, Ungar B, Lee S, Kim S, Eliakim R, Chowers Y. Cross-immunogenicity: antibodies to infliximab in Remicade-treated patients with IBD similarly recognise the biosimilar Remsima. *Gut* 2015; [DOI: 10.1136/ gutjnl-2015-309290]

35 **Sieczkowska J**, Jarzębicka D, Banaszkiewicz A, Plocek A, Gawronska A, Toporowska-Kowalska E, Oracz G, Meglicka M, Kierkus J. Switching Between Infliximab Originator and Biosimilar in Paediatric Patients with Inflammatory Bowel Disease. Preliminary Observations. *J Crohns Colitis* 2016; **10**: 127-132 [PMID: 26721942 DOI: 10.1093/ecco-jcc/jjv233]

36 **Cadila Healthcare Ltd.** Zydus Launches World's First Biosimilar of Adalimumab. Zydus Cadila. Available from: URL: http: //exemptia.com/zydus-launches-worlds-first-biosimilar-of-adalimumab-2/ [Accessed April 04, 2016].

37 **Bandyopadhyay S,** Mahajan M, Mehta T, Singh AK, Parikh A, Gupta AK, Kalita P, Patel M, Mendiratta SK. Physicochemical and functional characterization of a biosimilar adalimumab ZRC-3197. *Biosimilars* 2015: **5**: 1–18 [DOI: 10.2147/BS.S75573]

38 From Clinical trial registry India, a service of Indian National Institute of Medical Statistics (NIMS), Available from: URL: http: //ctri.nic.in/Clinicaltrials/showallp.php?mid1=7595&EncHid=&userName=adalimumab [Accessed April 04, 2016]

39 **CTRI/2013/10/004040.** Medicines Agency [database on the Internet]. London: Medicines Agency. Available from: URL: http: //www.ema.europa.eu/ema/index.jsp?curl=pages/about\_us/general/general\_content\_000109. jsp. And Central Drugs Standard Control Organization. Available from: http: //www.cdsco.nic.in/ [Accessed April 04, 2016].

40 **Gabbani T,** Deiana S, Bagnoli S, Annese V. Development, safety and efficacy of biosimilar adalimumab: the data so far. *Biosimilars* 2016; **6:** 1-7

41 **Murphy C,** Sugrue K, MohamadG, McCarthy J, Buckley M. Biosimilar but not the same. *J Crohns Colitis* 2014; **8** (suppl 1): P505

**P-Reviewer:** Feldman SR, Gomollon F, Thelwell C, Lakatos PL **S-Editor:** Qi Y **L-Editor: E-Editor:**

**Specialty type:** Gastroenterology and hepatology

**Country of origin:** Italy

**Peer-review report classification**

Grade A (Excellent): A

Grade B (Very good): B, B

Grade C (Good): C

Grade D (Fair): 0

Grade E (Poor): 0

**Table 1 Major real-world studies of CT-P13 in inflammatory bowel disease[40,41]**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Study | Design | Follow-up | Effect parameters | IBD | Nr | TNF-naive | Efficacy | | Safety | |
| **Clinical response (%, n/N)** | **Remission rate (%, n/N)** | **Adverse event (%, n/N)** | **IRR (%; n/N)** |
| Park *et al*[27]*,* 2015  South Korea | Open-label, retrospective, multicenter | 30 wk | CDAI  Mayo score | CD4 | 95 | 51 | 77.83(35/45) | 57.83(26/45) | 17.9 (17/95) | 2.1 (2/95) |
| UC | 78 | 62 | 72.25  (39/54) | 375  (20/54) | 26.9 (21/78) | 1.3 (1/78) |
| Jung *et al*[28]*,* 2015  South Korea | Open-label, retrospective, multicenter | 54 wk | CDAI  Mayo score  CRP | CD | 59 | 32 | 87.5c (7/8) | 75.0c  (6/8) | 0 (0/59) | 0 |
| UC | 51 | 42 | 100c (12/12) | 503  (6/12) | 11.8 (6/51) | NR |
| Kang *et al*[29]*,* 2015  South Korea | Open-label, case-series, tertiary center | 8 wk | CDAI  Mayo score | CD | 8 | 3 | 66.7c (2/3) | 66.73  (2/3) | 0 | NR |
| UC | 9 | 5 | 100c (5/5) | 100c  (5/5) | 0 | NR |
| Gecse *et al*[30]*,* 2015  Hungary | Open-label, prospective, observationalmulticenter | 14 wk | CDAI  FDA  Mayo score  CRP  PLT count | CD | 126 | 93 | 81.4 (79/97) | 53.6 (52/97) | 17.12  (36/210) | 6.62  (14/210) |
| UC | 84 | 68 | 77.6 (45/58) | 58.6 (34/58) |
| Farkas *et al*[31]*,* 2015  Hungary | Open-label, prospective, observational tertiary center | 8 wk | CDAI  Mayo score | CD | 18 | 16 | 37.51 (6/16) | 50 (8/16)1 | NR | NR |
| UC | 21 | 19 | 201 (3/15) | 66.71  (10/15) |
| Jahnsen *et al*[32]*,* 2015  Norway | Open-label, prospective, observational single-center | 14 wk | HBI  Mayo score  CRP  Calprotectin | CD | 46 | 33 | NR | 79 (34/43) | NR | 2.2 (1.46) |
| UC | 32 | 27 | NR | 56 (18/32) | NR | 3.1 (1/32) |
| Sieczkowska *et al*[35]*,* 2015.  Poland | Open-label, prospective, observationalswitching, pediatric | 8 mts | PCDAI  PUCAI  CRP | pCD | 325 | 26 | NR | 87.5 (28/32) | NR | 3.1 (1/32) |
| 5 mts | pUC | 75 | 6 | NR | 57.1 (4/7) | NR | 28.6 (2/7) |

1The patients who completed induction treatment; 2At week 30; 3In TNF-naïve patients only; 4Including fistulizing active CD (*n* = 12); 5 Patients had switched from infliximab to CT-P13. NR: Not Reported.