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Short communication

Production and characterisation of monoclonal antibodies specific for chicken interleukin-12

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Abstract

Using genetic immunisation of mice, we produced antibodies against chicken interleukin-12p40 (chIL-12p40), also known as IL-12β. After a final injection with a recombinant chIL-12p40 protein, several stable hybridoma cell lines were established which secreted monoclonal antibodies (mAbs) to this component of the heterodimeric IL-12 cytokine. Specific binding of three of the mAbs to COS-7 cell-derived recombinant chIL-12p40 and the chIL-12p70 heterodimer was demonstrated in an indirect ELISA, and in dot blots. Two of the mAbs were used to develop a capture ELISA, suitable for detecting both recombinant protein (chIL-12p40 and the heterodimeric p70 protein) and native chIL-12. The mAbs were further characterised to show utility in immunocytochemistry.

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1. Introduction

Interleukin-12 (IL-12) is a 70 kDa heterodimeric cytokine, comprising IL-12p35 (IL-12α) and IL-12p40 (IL-12β), which plays a crucial role in the initiation and progression of a Th1-type response (reviewed by Trinchieri, 2003). In infections caused by bacteria and intracellular parasites, IL-12 is produced by antigen-presenting cells within a few hours of infection. It acts as a pro-inflammatory cytokine, activating NK cells (Chan et al., 1991) and inducing IFN-γ production, which in turn enhances phagocytic and bactericidal activity of phagocytic cells and their ability to release IL-12 and other pro-inflammatory cytokines. Furthermore, IL-12 produced during the early stages of infection or inflammation determines the ensuing antigen-specific immune response, favouring differentiation of CD4+ T cells into Th1 cells, whilst inhibiting differentiation of Th2 cells through the resulting production of IFN-γ.

Until relatively recently, progress in understanding and dissecting the avian immune response to a variety of pathogens has been hampered by the lack of cross-reactivity and low level of sequence homology between avian and mammalian immune-related molecules. However, the availability of the chicken genome (International Chicken Genome Sequencing Consortium, 2004) has provided a unique resource to further our understanding of the general biology and more specifically the immune-related genes in the chicken (Kaiser et al., 2005). We are now able to measure expression of many genes, including most cytokines, at the mRNA level by real-time quantitative RT-PCR (qRT-PCR) (Eldaghayes et al., 2006; Kaiser and Stäheli, 2008); however, to date, there still remains a paucity of reagents available to measure the immune response in the chicken, particularly at the protein level. Indeed, although the two sub-units of the functional chicken IL-12p70 molecule were cloned some years ago (Balu and Kaiser, 2003; Degen et al., 2004), the only assays available to measure chicken IL-12 (chIL-12) at the protein level are...
an indirect bioassay based on the stimulation of IFN-γ synthesis or a non-specific assay measuring the proliferation of splenocytes (Degen et al., 2004).

The aim of this study was to generate monoclonal antibodies (mAbs) to chIL-12 for use in assays to specifically measure IL-12 production. Using a pair of the anti-chIL-12 mAbs generated, a capture ELISA was developed that could detect natural and recombinant chIL-12. The mAbs also show utility in immunocytochemistry.

2. Materials and methods

2.1. IL-12 expression

A NotI fragment containing the chIL-12p40 cDNA (Balu and Kaiser, 2003) was inserted into the NotI site in the polylinker of the eukaryotic expression vector pcI-neo (Promega, Southampton, UK) giving rise to pcI-neo-chIL-12p40.

ChFlexi-IL-12, a single-chain chIL-12p35-p40 heterodimeric construct cloned into pcDNA3.1 (Invitrogen, Paisley, Scotland) was a kind gift from W.G.J. Degen, International BV, Boxmeer, The Netherlands (Degen et al., 2004).

Both constructs were expressed in COS-7 cells (ex-COS) using a well-described DEAE-dextran transfection method (Lawson et al., 2000, 2001; Rothwell et al., 2004; Tregaskes and Young, 1997).

2.2. Monoclonal antibody production, purification and labelling

M Abs were generated following intramuscular genetic immunisation of mice with pcI-neo-chIL-12p40 (100 µg endotoxin-free DNA/mouse in a total volume of 100 µl PBS, 50 µg/hind quadriceps), following a previously described procedure (Rothwell et al., 2001). Following the fusion, hybridoma supernatants were screened for antibodies to chIL-12p40 by indirect ELISA, described below. Positive hybridomas were selected for cloning (by limiting dilution) and expansion. The isotype of each mAb was determined using the IsoStrip mouse mAb isotyping kit (Roche Diagnostics, Burgess Hill, UK), according to the manufacturer’s instructions.

M Abs were purified using HiTrap Protein G columns (GE Healthcare Life Sciences, Little Chalfont, UK) according to the manufacturer’s instructions. Concentrations of purified mAbs were determined by absorbance at 280 nm, and then dialysed extensively against PBS using 10,000 Da molecular weight cut-off (MWCO) Slide-A-Lyser cassettes (Perbio Science, Tattenhall, UK).

Purified mAbs were conjugated to biotin by incubating with ImmunoPure Sulfo-NHS-LC-Biotin (Perbio Science) for 2 h at room temperature (RT), as per the manufacturer’s instructions. Biotinylated mAbs were again dialysed against PBS using 10,000 Da MWCO Slide-A-Lyser cassettes.

2.3. Antibody assays

Indirect ELISA was performed as described previously (Rothwell et al., 2001). Briefly, supernatant from fusion wells (100 µl) or 50 µl of mouse serum diluted 1:200 in PBS containing 0.05% Tween 20 (PBS-T) was added to the wells of assay plates previously coated with recombinant chIL-12p40 (rchIL-12p40) ex-COS. Specifically-bound antibody was detected with a secondary biotinylated goat anti-mouse IgG (GE Healthcare Life Sciences), followed by streptavidin–horseradish peroxidase (AbD Serotec, Kidlington, UK). Peroxidase activity was revealed with o-phenylenediamine (OPD) substrate (Sigma, Poole, UK), and absorbance was read at 492 nm in a SpectraMax 250 microplate spectrophotometer system (Molecular Devices, Sunnyvale, CA, USA).

A capture ELISA was developed using the anti-chIL-12p40 mAbs described in this paper. Falcon Microtest III flexible assay plates (Becton–Dickinson, Oxnard, CA, USA) were coated by overnight incubation at 4 °C with capture mAbs (1–5 µg/ml in PBS, 50 µl/well). Plates were washed three times with PBS-T, and then blocked with 100 µl/well PBS-T containing 1% BSA (Sigma) for 2 h. After a further three washes in PBS-T, 50 µl/well recombinant or native IL-12-enriched culture supernatant were added, and incubated for 2 h at RT. Unbound protein was removed by washing with PBS-T, biotinylated detecting mAb was added (0.5–1 µg/ml in PBS, 50 µl/well) and plates were incubated for 1 h at RT. They were then washed three times, prior to the addition of 50 µl/well of streptavidin–horseradish peroxidase (AbD Serotec) diluted 1:500 in PBS-T and incubation for 1 h at RT. After washing three times in PBS-T, peroxidase activity was developed by adding 75 µl/well of Ready-to-use tetramethylbenzidine (TMB) substrate (Sigma) for 10–15 min at RT. The reaction was stopped by the addition of 75 µl/well of 0.5 M H2SO4. Absorbance was read at 450 nm in a SpectraMax 250 microplate spectrophotometer system (Molecular Devices).

Dot blots were performed by dotting recombinant cytokines or control samples onto Hybond C nitrocellulose membrane (GE Healthcare Life Sciences) and allowed to air-dry. Blots were then incubated in blocking solution (5% skimmed milk powder in PBS) overnight, at RT. After washing three times in PBS-T, they were incubated with the anti-chIL-12p40 mAbs, diluted 1:10 in blocking buffer, for 1 h at RT. Primary antibody was removed by washing three times in PBS-T and blots were then incubated with rabbit anti-mouse immunoglobulin conjugated to horseradish peroxidase (DAKO, Glostrup, Denmark) diluted 1:1000 in PBS, for 1 h at RT. After a further five washes in PBS-T, detection was carried out using enhanced chemiluminescence (ECL) (GE Healthcare Life Sciences), according to the manufacturer’s instructions.

2.4. Isolation of bone marrow-derived macrophages and stimulation to produce IL-12

Femurs of 5- to 6-week-old Rhode Island Red chickens were removed post-mortem and isolated from the surrounding muscle tissue using sterile instruments. Both ends of the bone were cut off and the marrow flushed out with RPMI 1640 medium, using a 21G needle and syringe. Clumps of marrow were disaggregated by pipetting and large debris excluded by passing the suspension through a 100-µm cell strainer. The cell suspension was...
washed in RPMI 1640, resuspended at 5 x 10^6 cells/ml in complete media (RPMI 1640 containing 5% chicken serum (Invitrogen), 1% L-glutamine, 1 U/ml penicillin and 1 µg/ml streptomycin) supplemented with rchGM-CSF (ex-COS, 1:100; Avery et al., 2004), plated out in 24-well plates and incubated for 7 days at 41 °C, 5% CO2. The adherent monolayer of cells were re-fed every 2–3 days, by carefully removing non-adherent cells and spent media, and replacing with fresh complete media containing rchGM-CSF. On day 7 of culture, cells were stimulated with a variety of compounds known to induce IL-12 expression: ConA (Sigma) (1 µg/ml); LPS (E. coli serotype 055:B5 (Sigma), 4 µg/ml); CpG DNA (pC-Neo plasmid DNA (Promega), 10 µg/ml); soluble CD40 ligand (CD40L or CD154) fusion protein (3 µg/ml) (Tregaskes et al., 2005); poly:C (Sigma) (30 µg/ml). All were used in the presence or absence of rchIL-12p40 mAbs (diluted 1:10 in PBsA, 1% bovine serum albumin, 0.1% sodium azide) (or appropriate isotype control mAbs) as the primary antibody. Staining was visualised by incubation with peroxidase substrate solution (Vector® NovaRED™) and subsequent counter-staining with haematoxylin, to produce red staining for the target cells and blue staining for the background.

3. Results and discussion

This paper describes the production and characterisation of murine anti-chIL-12p40 mAbs, following successful DNA immunisation of mice. Of the five mAbs generated, two have been used to successfully develop an IL-12-specific capture ELISA, as described below.

Following three DNA immunisations, two out of six mice showed good antibody responses, as measured by indirect ELISA, and one was used for a fusion. Fusion plates were also screened by indirect ELISA, and five IL-12p40-specific antibody-secreting hybridomas were selected for cloning, expansion and characterisation. Two mAbs (AV114 and AV140) were IgM and were not characterised further. The three remaining mAbs (AV134, AV135 and AV136) were IgG1 isotype, and all recognised rchIL-12p40 and rchIL-12p70 in both indirect ELISA (Fig. 1A) and dot blots (Fig. 1B). Fig. 1B shows that the mAbs are specific for chIL-12 and do not cross-react with recombinant mammalian (human or bovine) IL-12, nor with supernatant from COS cells transfected with pCl-neo alone, or pCl-neo expressing chIFN-γ. The three mAbs only bind to IL-12p40 in its native form, but do not recognise denatured antigen (Fig. 1B).

Various combinations of the three IgG1 mAbs, at different dilutions, were used to develop an IL-12 capture ELISA. Since the three mAbs were of the same isotype, unconjugated mAbs were used as capture Abs, whilst biotinylated mAbs were used as the detecting mAbs. All three mAbs worked in all possible combinations, with the optimal pair being AV134 (capture mAb, at 2 µg/ml) and biotinylated–AV134 (detecting mAb, at 0.5 µg/ml), resulting in the greatest sensitivity. The capture ELISA readily detected recombinant chIL-12p40 and chIL-12p70 derived from COS cells (Fig. 2), in a dose-dependent manner, and was then used to identify “native” IL-12 expressed by stimulated primary macrophages in vitro (Fig. 3A). Bone marrow cells were cultured in vitro for 7 days in the presence of rchGM-CSF to generate primary macrophages, which were then stimulated with a variety of compounds known to induce IL-12 production in mammals, including TLR agonists such as LPS, CpG DNA, and polyI:C and host-related stimuli such as CD40L, with or without IFN-γ priming. Cells and supernatants were harvested at 4.5 and 18 h post-stimulation (hps). RNA was isolated from the cells for subsequent analysis by qRT-PCR (Fig. 3B) and supernatants were assayed for IL-12 using the capture ELISA (Fig. 3A).

2.5. Real-time quantitative RT-PCR

IL-12p35 and IL-12p40 mRNA levels were quantified by TaqMan qRT-PCR, using a well-described method (Avery et al., 2004; Eldaghyes et al., 2006; Rothwell et al., 2004). Primers and probes for IL-12p35, p40 and 28S RNA-specific amplification have been described previously but for clarity their sequences are as follows: IL-12p35 forward primer, GGCGAAGCCAGAGGAAACT; reverse, TGGCCGCTGCAAACG; probe, AGGACCGCTACGGACGACGACGA. IL-12p40 forward primer, CGACGACCGATTTGCACGTC; probe, AGGACCGCTACGGACGACGACGA. The three mAbs only bind to IL-12p40 in its native form, but do not recognise denatured antigen (Fig. 1B).

2.6. Immunocytochemistry

Rhode Island Red chickens were infected at three weeks of age with 10^3.7 EID50 of the virulent infectious bursal disease virus (IBDV) strain F52/70 (Bygrave and Faragher, 1970) by the intranasal route in a total volume of 100 µl (Eldaghyes et al., 2006). Bursal tissue from 5 infected and 3 age-matched uninfected control birds at 4 days post-infection was snap-frozen in OCT (Sakura Finetek, Thatcham, UK). Frozen sections (6–8 µm) of the bursa of Fabricius were cut using a cryostat, placed onto glass slides, fixed in acetone for 10 min and air-dried. Staining was carried out using a Vectastain® ABC anti-mouse IgG HRP staining kit (Vector Laboratories, Burlingame, CA, USA) following the manufacturer’s instructions, using the anti-chIL-12p40 mAbs (diluted 1:10 in PBsA, 1% bovine serum albumin, 0.1% sodium azide) (or appropriate isotype control mAbs) as the primary antibody. Staining was visualised by incubation with peroxidase substrate solution (Vector® NovaRED™) and subsequent counter-staining with haematoxylin, to produce red staining for the target cells and blue staining for the background.
Unsurprisingly, no IL-12 was detected in the culture supernatants harvested at 4.5 hps. However, IL-12 was detected in the supernatants harvested 18 hps from macrophages stimulated with LPS and IFN-γ, and to a lesser extent in those stimulated with LPS and CD40L (Fig. 3A). Analysis of IL-12 mRNA expression by qRT-PCR (Fig. 3B) showed significant up-regulation of IL-12p35 and IL-12p40 in the same samples at 4.5 hps. IL-12p40 mRNA was also
up-regulated in macrophages stimulated with LPS alone or CpG DNA when compared to unstimulated macrophages, and although IL-12p35 was also detected in those samples, it was not as highly expressed as in the LPS + IFN-γ- and LPS + CD40L-stimulated samples. IL-12p35 mRNA was not detected in cells cultured in media alone, in the presence of CD154 or polyI:C alone, or in the presence of CD154 and rchIFN-γ or polyI:C. By 18 hps, IL-12p40 mRNA expression was no longer significantly up-regulated, whilst IL-12p35 was still up-regulated in some cells (data not shown). Biologically active IL-12 (IL-12p70) can only be produced in cells that co-express both p35 and p40 subunits (Gubler et al., 1991), and in mammals IL-12p35 is ubiquitously and constitutively expressed, so it is the more tightly regulated and restricted expression of IL-12p40 that determines a cell’s ability to produce functional IL-12 (Gately et al., 1998). In contrast, in the chicken, IL-12p40 mRNA is ubiquitously expressed in a wide variety of tissues (Balu and Kaiser, 2003), whilst expression of IL-12p35 is more tightly controlled (Balu, 2005; Degen et al., 2004), thus determining the production of the functional p70 molecule. The capture ELISA data (Fig. 3A), in concert with the qRT-PCR data (Fig. 3B), indicates that it is both the expression of p35 and the abundance of p40 that determines the amount of IL-12p70 produced. We have shown that, as in mammals, effective induction of chIL-12 in vitro requires at least two different signals (Snijders et al., 1998), specifically bacterial LPS (activating the TLR4 pathway) along with an ‘endogenous’ signal such as engagement of the CD40-CD40L signalling pathway or co-stimulation via IFN-γ.

Using qRT-PCR, we had previously shown that IL-12p35 mRNA expression is up-regulated in the bursa two to four days post-infection (dpi) with virulent IBDV F52/70, whilst IL-12p40 is constitutively expressed in both uninfected and infected birds (Eldaghayes et al., 2006). Bursal sections (4 dpi) from the same IBDV-infection experiment (Eldaghayes et al., 2006) were stained with the anti-chIL-12p40 mAbs described herein, to investigate their utility in immunocytochemistry. Clear positive staining of IL-12-producing cells (using both mAbs, AV135 and AV136) was seen in the bursae of infected birds (Fig. 4B and D) when compared to bursal sections from age-matched control birds (Fig. 4A and C). Positively stained cells are mainly seen in the cortex of the bursa and at the cortico-medullary junction, with some IL-12-positive cells in the medulla, as well as in the interfollicular tissue. IBDV infection results in gross bur-
The authors thank staff in the experimental animal houses for inoculating and maintaining the mice, and maintenance of the birds. We wish to thank Brenda Jones and Gillian Hill for carrying out the fusions and hybridoma cloning; Winfried Degen for providing us with the pFlexy-IL-12 clone, John Young for the kind gift of the recombinant chCD154 fusion protein, and Ibrahim Eldaghayes for providing IBDV-infected tissue samples for immunocytochemistry. This work was supported by the Biotechnology and Biological Sciences Research Council (Institute Strategic Programme Grant funding to IAH and The Roslin Institute).

**References**


