10. Eden AN, Kaufman A, Yu R. Corticosteroids and croup: controlled double-blind study. *JAMA* 1967; **200:** 403–04.
11. Koren G, Frand M, Barzilay Z, MacLeod SM. Corticosteroid treatment of laryngotracheitis v spasmodic croup in children. *Am J Dis Child* 1983; **137:** 941–44.
12. Super DM, Cartelli NA, Brooks LJ, Lembo RM, Kumar ML. A prospective randomised double-blind study to evaluate the effect of dexamethasone in acute laryngotracheitis. *J Pediatr* 1989; **115:** 323–29.
13. Phelan PD, Landau LI, Olinsky A. Respiratory illness in children, 3rd ed. Oxford: Blackwell, 1990: 47–88.
14. Tibballs J. Equipment for paediatric intensive care, 3rd ed. In: Oh TE, ed. Intensive care manual. Sydney: Butterworth, 1990: 666–72.
15. Rivera R, Tibballs J. Complications of endotracheal intubation and mechanical ventilation in infants and children. *Crit Care Med* 1992; **20:** 193–99.
16. Freezer N, Butt W, Phelan P. Steroids in croup: do they increase the incidence of successful extubation? *Anaesth Intens Care* 1990; **18:** 224–28.
17. Casagrande JT, Pike MC. An improved approximate formula for calculating sample sizes for comparing two binomial proportions. *Biometrics* 1978; **34:** 483–86.
18. Christensen E. Multivariate survival analysis using Cox's regression model. *Hepatology* 1987; **7:** 1346–58.
19. Altman DG. Practical statistics for medical research. London: Chapman and Hall, 1991: 365–95.
20. Smith DS. Corticosteroids in croup: a chink in the ivory tower? *J Pediatr* 1989; **115:** 256–57.
21. Narcy P. Corticotherapie et laryngite aigue sous-glottique. *Arch Fr Pediatr* 1991; **48:** 389–90.
22. Tunnessen WW, Feinstein AR. The steroid-croup controversy: an analytic review of methodologic problems. *J Pediatr* 1980; **96:** 751–56.
23. Kairys SW, Olmstead EM, O'Connor GT. Steroid treatment in laryngotracheitis: a meta-analysis of the evidence from randomised trials. *Pediatrics* 1989; **83:** 683–93.
24. Kuusela AL, Vesikari T. A randomised double-blind placebo-controlled trial of dexamethasone and racemic epinephrine in the treatment of croup. *Acta Paediatr Scand* 1988; **77:** 99–104.

Humanised monoclonal antibody therapy for rheumatoid arthritis

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Monoclonal antibodies that target T cells have shown some benefit in rheumatoid arthritis although responses have not been long lasting. This is partly due to insufficient therapy consequent upon antibody immunogenicity. Use of humanised antibodies, which are expected to be less foreign to man than conventional rodent antibodies, might overcome this problem. We therefore assessed in a phase 1 open study the potential of a "lymphocyte depleting" regimen of the humanised monoclonal antibody CAMPATH-1H in 8 patients with refractory rheumatoid arthritis.

Apart from symptoms associated with first infusions of antibody, adverse effects were negligible. Significant clinical benefit was seen in 7 patients, lasting for eight months in 1. After one course of therapy, there was no measurable antiglobulin response, although 3 out of 4 patients have become sensitised on retreatment.

Humanisation reduces the immunogenicity of rodent antibodies but anti-idiotype responses may still be seen on repeated therapy, even in patients sharing immunoglobulin allotype with the humanised antibody.

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Introduction

Monoclonal antibodies (mAbs) are being studied for treatment of autoimmune and inflammatory diseases.[1] Rheumatoid arthritis is a common, progressive, crippling disease; because of its association with HLA, and the response to therapies such as thoracic duct drainage, total lymphoid irradiation, and cyclosporin, there is compelling evidence that T cells have a crucial role in its pathogenesis. Although mAbs that target T cells have shown benefit in rheumatoid arthritis, responses have been of limited duration. Furthermore, the therapeutic "window" within which antibodies could be used has been narrow because of the antiglobulin response against the therapeutic agent.[2,3] To reduce to a minimum the immunogenicity of therapeutic antibodies, "reshaping" by genetic engineering has been used to convert rodent antibodies to a human form.[4,5] Such "humanised" antibodies should appear less foreign to man than do conventional rodent antibodies. With existing techniques, however, "humanisation" leaves open the chance for anti-idiotypic and anti-allotypic responses. We have assessed the potential of humanised antibodies for treatment of rheumatoid arthritis.

Patients and methods

Patients

Characteristics of the 8 patients are shown in table I. They fulfilled the American Rheumatism Association criteria for rheumatoid arthritis and had active disease as defined by three of the following four criteria: Ritchie articular index > 10, early morning stiffness > 45 min, erythrocyte sedimentation rate (ESR) > 30 mm per hour, joint score > 10. 7 patients were seropositive. Their disease had proved unresponsive to a current and at least one other second-line agents, and these had been stopped at least four weeks before administration of CAMPATH-1H. Patients were allowed to continue with non-steroidal anti-inflammatory drugs (NSAIDs) and an existing dose of prednisolone (up to 20 mg daily). They were otherwise healthy, and had normal renal and hepatic function. Approval of the local ethics committee and informed consent of the patients were obtained.

Treatment

CAMPATH-1H—CAMPATH-1H is a human IgG_1 mAb that is specific for the glycoprotein CDw52, an antigen present on all lymphocytes and some monocytes.[6] This mAb was derived by humanisation of the rodent antibody CAMPATH-1G.[4] Therapeutic-grade antibody was produced in Chinese hamster ovary cells grown in a hollow-fibre continuous culture system (Acusyst-Junior, Endotronics Inc, Minneapolis, MN, USA) and was purified on protein A. The antibody was formulated in

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TABLE I—PATIENT CHARACTERISTICS

Patient, age (yr)	Disease duration (yr)	ESR (mm/h)	CRP (mg/l)	Ritchie*	Joint score*	Morning stiffness (min)	Global assess-ment†	Rheumatoid factor (IU/ml)	Previous therapy	Prednisolone (mg/day)
A, 32	2	100	160	10	17	30	181	40	G, P, M, S	7·5
B, 62	13	95	45	34	15	300	286	2112	G, P, M, S, γIFN	10·0
C, 69	9	64	112	36	16	120	212	0	G, P, M, S, A, CyA	0
D, 46	16	48	45	22	12	45	105	125	G, P, M, S	7·5
E, 50	19	55	94	38	18	300	283	121	G, P, S, C	20·0
F, 61	35	40	90	34	11	5	299	56	G, P, S, CyA	0
G, 55	7	62	114	39	16	360	298	420	G, P, M, S, C, CyA	10·0
H, 68	3	80	128	27	12	60	175	233	S, Romazarit	0

*Maximum attainable Ritchie and joint scores were 78 and 26, respectively.
†Sum of 4 scores (max = 100 each) measured on a 10 cm visual analogue scale representing night pain, rest pain, general wellbeing, and functional ability
ESR = erythrocyte sedimentation rate, CRP = C-reactive protein.
G = gold, P = penicillamine, M = methotrexate, S = sulphasalazine, γIFN = γ-interferon, A = azathioprine, CyA = cyclosporin, C = cyclophosphamide

phosphate-buffered saline and after sterility and endotoxin checks it was stored at −30°C before administration. Before infusion it was diluted in 100 ml (first treatment) or 500 ml (retreatment) normal saline.

Therapeutic regimen—Patients were admitted to hospital for antibody therapy. CAMPATH-1H was given by intravenous infusion over 2–4 hours, during which vital signs were recorded every 15 min. A course of therapy lasted for 10 days, and consisted of 4 mg antibody daily for 5 days followed by 8 mg antibody daily for 5 days. Between daily infusions, patients were fully mobile but did not receive physiotherapy. A second course of therapy consisted of 40 mg antibody daily for 5 days.

Assessment

Ritchie articular index and joint score were assessed immediately before treatment, and daily during treatment. Duration of morning stiffness, patient's global assessment (sum of 4 scores representing night pain, rest pain, general wellbeing, and functional ability, each measured on a visual analogue scale), joint thermography, ESR, C-reactive protein, and full blood count with differential white-cell count were also recorded. A similar assessment was done every week after therapy for 1 month, and then every month. Patients were judged to have relapsed if a further second-line agent, an increase in prednisolone dose, or a second course of CAMPATH-1H was administered to control recurrent symptoms.

Lymphocytes and allotyping—The following stains were used to determine subsets of peripheral blood lymphocytes: CD4 = $CD4^+$ $CD8^-$, and CD8 = $CD8^+$ $CD4^-$ (Simultest 349508, Becton Dickinson, USA); natural killer (NK) cells = $CD16^-/CD56^+$ $CD3^-$ (Simultest 349515); B-cells = $CD19^+$ (Dako R808, High Wycombe, Bucks, UK). The immunoglobulin allotype of each patient was determined in a haemaglutination inhibition assay with a commercial kit (Central Laboratory of the Netherlands Red Cross Blood Transfusion Service, Amsterdam).

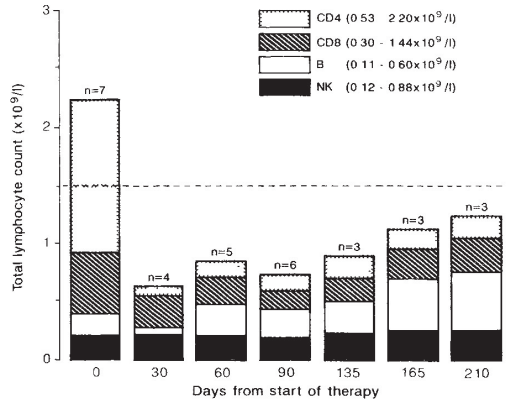

Fig 1—Lymphocyte subset counts.

n refers to no of patients analysed at each time point (subset data could not be obtained when total lymphocyte count $< 0.4 \times 10^9$/l, and pre-treatment values not available for patient E) Horizontal line represents lower limit of normal range for total lymphocyte count

CAMPATH-1H—Serum CAMPATH-1H concentrations were measured by immunofluorescence with human peripheral blood lymphocytes. 5×10^5 cells (suspended in wash buffer [phosphate buffered saline containing 0·2% bovine serum albumin and 0·01% azide]) were incubated for 1 h on ice with an equal volume of patient serum (heat-inactivated at 56°C for 30 min). After extensive washing, bound CAMPATH-1H was sought with fluorescein-isothiocyanate-conjugated monoclonal anti-human IgG_1 immunoglobulin (Sigma F0767 [Poole, Dorset, UK] diluted 1/100 in wash buffer containing 10% heat-inactivated normal rabbit serum). Cells were fixed, and relative fluorescence intensity was measured by means of a FACScan (Becton Dickinson). A standard curve of median fluorescence values obtained with known concentrations of CAMPATH-1H (diluted in heat-inactivated normal human serum) was used to determine absolute concentrations in the sera. The sensitivity of the assay was between 40 and 100 ng/ml.

Antiglobulin response—Two assays were used to assess antiglobulin reactivity in patients' sera. Serum samples from all patients were tested in a double-capture enzyme-linked immunosorbent asssay (ELISA).[7] This test is a sensitive and specific assay for detecting antiglobulins able to bind monovalently to CAMPATH-1H, thereby excluding low-affinity antiglobulins and rheumatoid factors; an additional advantage is that it discriminates between anti-idiotype, anti-isotype, and anti-allotype antiglobulins. This assay could detect 10 ng/ml monoclonal anti-CAMPATH-1 idiotypic antibody (YID 13·9),[7] and 2 μg/ml polyclonal goat anti-human IgG (Fc-specific, Sigma I2136). Sera that were positive in the ELISA were further analysed with a functional read-out that measured their ability to block binding of CAMPATH-1H to the CAMPATH-1 antigen. 25 μl heat-inactivated serum was mixed with an equal volume of CAMPATH-1H (4 μg/ml in heat-inactivated normal human serum). 5×10^5 peripheral blood lymphocytes were then added and bound CAMPATH-1H was sought. Blocking activity was expressed as the serum titre that inhibited CAMPATH-1H binding by 50%. This was equivalent to 125 ng/ml YID 13·9. Whilst providing a functional measure of antiglobulin neutralising activity, this assay may not be completely specific. For example, soluble CAMPATH-1 antigen also inhibits in this assay (unpublished).

Statistical analysis—Patient data were analysed with the Mann-Whitney U test, comparing values after treatment with those on day 0. Data obtained after relapse were excluded from statistical analysis to avoid the introduction of bias by additional therapies.

Results

Clinical findings

The first infusion of antibody led to a rapid fall in total lymphocyte count in all patients. Lymphopenia was evident as early as an hour after the start of the first infusion, when systemic symptoms of fever (up to 40°C), rigors, and nausea developed in all patients; hypotension developed in 1 patient. These symptoms lasted for 2–3 hours and were more pronounced in patients receiving 40 mg of antibody at

TABLE II—CLINICAL OUTCOME AFTER A SINGLE COURSE OF TREATMENT

Index	Day*					
	0 [8]	10 [8]	28 [8]	56 [7]	90 [7]	125 [5]
Ritchie	34 (10–39)	10 5 (0–29)†	9·5 (1–32)†	9·0 (0–25)†	11·0 (0–34)†	13 (2–26)†
Joint score	16 (12–18)	7 (1–14)†	8·5 (2–14)†	7 (0–13)†	12 (6–14)†	12 (3–14)†
Morning stiffness (min)	90 (5–360)	30 (0–240)	10 (0–300)	30 (0–120)	60 (0–120)	30 (0–120)
Global score	247 (61–299)	86 (4–318)	74 (21–308)	59 (10–368)	126 (4–395)	136 (8–271)
ESR (mm/h)	58 (40–100)	76 (8–120)	61 (20–120)	66 (16–104)	60 (12–105)	84 (26–110)
CRP (mg/l)	103 (45–160)	79 (23–120)	63 (23–108)	70 24–150)	81 (54–212)	136 (74–236)

Values are median (range) for each index at each time point *Number in square brackets refers to patients remaining in study at each time point
†Significant at $p < 0.05$ by Mann-Whitney U test

TABLE III—SEROLOGICAL AND CLINICAL RESPONSES TO CAMPATH-1H THERAPY

Patient	Antiglobulin response*		Blocking activity†			Duration of response (days)	
	After first treatment	After retreatment	Before treatment	After first treatment	After retreatment	First	Retreatment
A	<0·01	..	<1/4	1/64	..	140	..
B	<0·01	5·0	1/8	1/32	1/256	140	>200
C	<0·01	..	<1/4	<1/4	..	84	..
D	<0·01	25·0	1/4	1/16	1/512	166	60
E	<0·01	0·01	<1/4	1/4	1/32	250	>90
F	<0·01	..	<1/4	<1/4	..	94	..
G	<0·01	..	<1/4	1/4	..	37	..
H	<0·01	<0·01	<1/4	<1/4	<1/4	126	>200

*As measured by ELISA, and expressed in μg/ml equivalents of the monoclonal anti-idiotype YID 13·9, which recognises the CAMPATH-1H idiotype
†Blocking activity refers to the ability of patients' sera to inhibit by 50% the binding of 2 μg/ml CAMPATH-1H to antigen on PBL, this is equivalent to approximately 125 ng/ml of the monoclonal anti-idiotype antibody YID 13 9

the start of retreatment. Lymphocyte counts remained suppressed for several months after therapy (fig 1). The latest values (normal range $1{\cdot}5–4{\cdot}0 \times 10^9$/l) in the first patients treated are $0{\cdot}43 \times 10^9$/l at 351 days (patient A), $1{\cdot}22 \times 10^9$/l at 225 days (B), $0{\cdot}48 \times 10^9$/l at 369 days (C), $0{\cdot}79 \times 10^9$/l at 185 days (D), and $0{\cdot}22 \times 10^9$/l at 259 days (E). Subset analysis showed that NK cells were spared after CAMPATH-1H treatment, consistent with in-vitro observations of the rat IgM mAb CAMPATH-1M.[8] B-cell numbers had returned to normal range by day 60. CD8 lymphocyte numbers were approaching normal range by day 210, whereas CD4 cells remained suppressed at this time.

In 7 patients there was an impressive, sustained response to therapy as shown by clinical reduction in joint swelling and improvement in thermography. Additionally, there were statistically significant improvements in Ritchie articular index and joint score lasting until day 125 (table II). There was no change in the ESR or C-reactive protein concentration with therapy, and no correlation between clinical relapse and lymphocyte count. Duration of remission lasted from 12 weeks to 8 months (table III). 4 patients have now been re-treated (table III). 1 patient was withdrawn from therapy because of a strong first-dose reaction; nonetheless, his disease improved for 60 days after a single dose of 40 mg CAMPATH-1H. The other patients continue to show therapeutic benefit up to 200 days after retreatment. In 2 of them response duration has surpassed that obtained with their first course of antibody treatment.

Apart from the first-dose response (see above) and similar but milder symptoms after the second dose, therapy was well tolerated. Culture-negative mouth ulceration developed in the first 2 treated patients, but this was not seen in subsequent patients given prophylactic amphotericin and antibacterial mouthwashes. Mild herpes simplex mouth ulceration developed in patient D but responded to topical therapy with acyclovir.

TABLE IV—IMMUNOGLOBULIN ALLOTYPES OF THE PATIENTS

—	Immunoglobulin	
	γ1 heavy chain	κ light chain
Patient		
A	G1m 1, 2, 3, 17	Km 3
B	G1m 3*	Km 1, 3
C	G1m 3	Km 1, 3
D	G1m 1, 2, 17	Km 1, 3
E	G1m 1, 17	Km 3
F	G1m 3*	Km 3
G	G1m 3	Km 3
H	G1m 1, 3, 17	Km 3
CAMPATH-1H	G1m 1, 17	Km 3

*Patients could not be reliably typed for G1m 1, 2, and 17 allotypes (see text)

Laboratory findings

Allotyping—The immunoglobulin allotypes are shown in table IV. Despite the small number of patients, these data accord with other published results. In particular, the G1m 1, 2, 3, 17 allotype has been shown to be more common and the G1m 1, 3, 17 less common in patients with rheumatoid arthritis.[9] CAMPATH-1H has the allotype G1m 1, 17, Km3.[5] All our patients possessed the Km3 light-chain allotype but at least 2 differed in heavy-chain allotype from CAMPATH-1H and therefore had the potential to make an anti-allotype response. It was not possible to achieve a consistent assessment of G1m 1, 2, or 17 allotype for patients B and F, possibly because of rheumatoid factors interfering with the haemagglutination inhibition assay.

CAMPATH-1H—Trough antibody concentrations remained below 1 μg/ml in all patients (fig 2) until dose escalation when they reached between 1 and 5 μg/ml. The mean value 24 hours after the last dose of antibody was about 2·3 μg/ml. Antibody concentrations fell with a half-life of less than a week, so that 2 weeks after therapy, antibody was undetectable in all but 2 patients (F, G), in whom antibody concentrations were 40 ng/ml at 25 days and 80 ng/ml at 19 days, respectively. It should be noted that about 10 μg/ml of CAMPATH-1H is needed to saturate surface receptors (CDw52) on peripheral blood lymphocytes in vitro. In all patients completing a second course of treatment trough antibody values reached at least 5 μg/ml during therapy (fig 2).

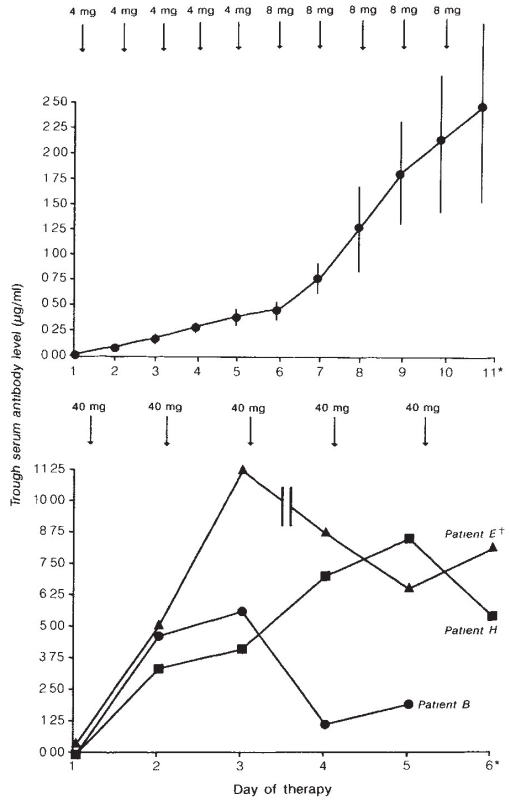

Fig 2—Mean serum CAMPATH-1H concentrations during first course of treatment (top) and during retreatment in 3 patients (bottom).

Bars = SD; arrows show doses administered. *Value is 24 hours after last dose of antibody. †48 hours between third and fourth doses of antibody.

Antiglobulin response (table III)—By double-capture ELISA, anti-CAMPATH-1H antiglobulins were not detected in any patient after one course of therapy, including the 2 patients differing in heavy chain allotype from CAMPATH-1H. By contrast, 3 of the 4 retreated patients (B, D, E) developed antiglobulins 6–10 days after the end of retreatment. 2 of these had a pure anti-idiotype response and they shared heavy-chain allotype with CAMPATH-1H. It was not possible to allotype patient B reliably, and the presence of a non-idiotype component in this patient's serum suggests an allotype mismatch. In the functional assay, sera from these 3 patients were able to inhibit the binding of CAMPATH-1H to human peripheral blood lymphocytes as predicted. Unexpectedly, however, sera from these and a further 2 patients also showed much weaker blocking activity 6–15 days after the first course of therapy. This may represent a weak primary antiglobulin response. However, it should be noted that in 2 of these patients weak activity could be detected even before therapy (and therefore may not represent specific antiglobulins but perhaps soluble CAMPATH-1H antigen or an effect of rheumatoid factors).

Discussion

To our knowledge this study is the first assessment of humanised mAb treatment for rheumatoid arthritis. We were unable to detect a significant antiglobulin response after one course of therapy but 3 out of 4 retreated patients developed antiglobulins and these were able to inhibit the binding of CAMPATH-1H to its antigen. We cannot conclude from these results whether an allotype mismatch increases the likelihood of an antiglobulin response to CAMPATH-1H, but it is now clear that even in the best possible situation of allotype matching, an anti-idiotype response may still be elicited. This finding accords with predictions from animal experiments.[10,11] Our data agree with experience of rat mAb CAMPATH-1G treatment for resistant rejection in transplant recipients.[12] With an equivalent assay to ours, an antiglobulin response was detected in 11 of 14 patients, between 11 and 18 days after a single course of mAb therapy, even with concurrent immunosuppression, which generally reduces the incidence of antiglobulin responses. In that transplant study patients received 5–10 mg/day of CAMPATH-1G for 6–10 days and most patients mounted a mixed (anti-isotype and anti-idiotype) antiglobulin response.

The identity of the blocking activity detected in some sera before and after one course of treatment in our study is unclear; it may represent a soluble form of the CAMPATH-1 antigen or perhaps low affinity antiglobulins, but discriminating between these options is difficult in view of the low titres. Whatever the nature of this blocking activity, effective serum antibody values and a sustained therapeutic response were seen upon re-treatment.

The side-effects observed in this study were acceptable. The first-dose response accompanied lympholysis and was presumably mediated by released cytokines. Similar symptoms are seen in patients receiving OKT3, a mAb directed to CD3 epsilon chain on human T cells. In that setting, cytokines are released as a result of T-cell activation, and a combination of tumour necrosis factor alpha and interleukin-1 can account for the clinical findings.[13] Apart from occasional oral ulceration infective complications were not seen in our patients. This observation mirrors that in laboratory animals, which stay healthy despite many weeks of anti-T cell antibody therapy, perhaps because of normal levels of neutrophils and monocytes. Infective complications, including herpes simplex infection, have been reported during antibody therapy but usually in association with additional potent immunosuppression.[14,15]

Animal experiments conducted in our own laboratories suggest that it may eventually be possible to control autoimmune states with single courses of antibody therapy by inducing tolerance to the putative autoantigen.[16] However, until appropriate regimens are available for human therapy, inflammation must be controlled by alternative means; antibodies seem to be the most potent agents available. Already they have been used to treat otherwise refractory cases of psoriasis[17] and inflammatory bowel disease,[18] and our study extends our knowledge of their use in rheumatoid arthritis. Although the improvements we observed were generally modest, it is remarkable that they were obtained with such small doses of antibody. To maximise our chance of targeting most peripheral lymphocytes, we doubled the dose of CAMPATH-1H administered after day 5 but serum concentrations were still below those required to saturate peripheral blood lymphocytes. Future studies must take advantage of the potent effects of CAMPATH-1H, whilst investigating ways of maximising therapeutic benefit. Our current re-treatment protocol is designed to ask whether a higher dose of mAb will improve outcome, and preliminary data are encouraging; 2 of 3 evaluable patients have now achieved an increased response duration on re-treatment. Alternatively, additional benefit may derive from combination therapy. Thus sequential treatment with CAMPATH-1H and a CD4 mAb gave a longer-lasting

remission (>3 years) than did CAMPATH-1H alone in a patient with vasculitis (ref 19 and M. Lockwood, personal communication), suggesting that this combination can induce tolerance. It is also possible that CAMPATH-1H will prove less immunogenic when administered in higher doses. Thus, mice do not make an antiglobulin response against CD4 mAbs provided a dose above a critical minimum is given.[20]

The variation in clinical response that we recorded may reflect the complex pathogenesis of rheumatoid arthritis. One hypothesis is that monocytes are the cell type that ultimately bring about the tissue damage seen in late disease,[21] but all the data from studies using mAbs and other T-cell targeted therapies suggest that, if this hypothesis is true, they must be driven by self-reactive T cells.[1] The rapid improvements seen in our patients point to an inflammatory role for T cells in late disease. By contrast, the lack of impact on ESR and C-reactive protein concentrations suggests that in rheumatoid arthritis the acute-phase response is driven by monocyte-derived cytokines.[22] Use of a two-tiered approach that targets both T cells and monocytes may be the ultimte requirement. The reduced immunogenicity of CAMPATH-1H compared with rodent antibodies and the consequent ability to retreat patients with higher doses or with other mAbs, will enable us to learn how to use mAbs to their best advantage both in rheumatoid arthritis and in other autoimmune diseases.

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REFERENCES

1. Waldmann H. Manipulation of T-cell responses with monoclonal antibodies. *Annu Rev Immunol* 1989; **7:** 407–44.
2. Watts RA, Isaacs JD. Immunotherapy of rheumatoid arthritis. *Ann Rheumatol* 1992; **51:** 577–79.
3. Isaacs JD. The antiglobulin response to therapeutic antibodies. *Semin Immunol* 1990; **2:** 449–56.
4. Riechmann L, Clark M, Waldmann H, Winter G. Reshaping human antibodies for therapy. *Nature* 1988; **332:** 323–27.
5. Gorman SD, Clark MR. Humanisation of monoclonal antibodies for therapy. *Semin Immunol* 1990; **2:** 457–66.
6. Hale G, Xia M-Q, Tighe HP, Dyer MJS, Waldmann H. The CAMPATH-1 antigen (CDw52). *Tissue Antigens* 1990; **35:** 118–27.
7. Cobbold SP, Rebello PRUB, Davies HFfS, Friend PJ, Clark MR. A simple method for measuring patient anti-globulin responses against isotypic or idiotypic determinants. *J Immunol Methods* 1990; **127:** 19–24.
8. Hale G, Bright S, Chumbley G, et al. Removal of T cells from bone marrow for transplantation: a monoclonal anti-lymphocyte antibody that fixes human complement. *Blood* 1983; **62:** 873.
9. Puttick AH, Briggs DC, Welsh KI, Williamson EA, Jacoby RK, Jones VE. Genes associated with rheumatoid arthritis and mild inflammatory arthritis. II. Association of HLA with complement C3 and immunoglobulin Gm allotypes. *Ann Rheum Dis* 1990; **49:** 225–28.
10. Benjamin RJ, Cobbold SP, Clark MR, Waldmann H. Tolerance to rat monoclonal antibodies: implications for serotherapy. *J Exp Med* 1986; **163:** 1539–52.
11. Bruggemann M, Winter G, Waldmann H, Neuberger MS. The immunogenicity of chimeric antibodies. *J Exp Med* 1989; **170:** 2153.
12. Friend PJ, Waldmann H, Hale G, et al. Reversal of allograft rejection using the monoclonal antibody, CAMPATH-1G. *Transplant Proc* 1991; **23:** 2253–54.
13. Chatenoud L, Bach J-F. OKT3 in allogeneic transplantation: clinical efficacy, mode of action, and side effects. In: Burlingham WJ, ed. A critical analysis of monoclonal antibody therapy in transplantation. Boca Raton: CRC Press, 1992.
14. Oh CS, Stratta RJ, Fox BC, Sollinger HW, Belzer FO, Maki DG. Increased infection risk associated with the use of OKT3 for treatment of steroid resistant rejection in renal transplantation. *Transplantation* 1988; **45:** 68–73.
15. Friend PJ, Hale G, Waldmann H, et al. Campath-1M-prophylactic use after kidney tranplantation. *Transplantation* 1989; **48:** 248–53.
16. Cobbold SP, Martin G, Waldmann H. The induction of skin graft tolerance in major histocompatibility complex-mismatched or primed recipients: primed T cells can be tolerized in the periphery with anti-CD4 and anti-CD8 antibodies. *Eur J Immunol* 1990; **20:** 2747–55.
17. Prinz J, Braun-Falco O, Meurer M, et al. Chimaeric CD4 monoclonal antibody in treatment of generalised pustular psoriasis. *Lancet* 1991; **338:** 320–21.
18. Emmrich J, Seyfarth M, Fleig WE, Emmrich F. Treatment of inflammatory bowel disease with anti-CD4 monoclonal antibody. *Lancet* 1991; **338:** 570–71.
19. Mathieson PW, Cobbold SP, Hale G, et al. Monoclonal-antibody therapy in systemic vasculitis. *N Engl J Med* 1990; **323:** 250–54.
20. Gutstein NL, Seaman WE, Scott JH, Wofsy D. Induction of tolerance by administration of monoclonal antibody to L3T4. *J Immunol* 1986; **137:** 1121.
21. Firestein GS, Zvaifler NJ. How important are T cells in chronic rheumatoid arthritis? *Arthritis Rheum* 1990; **33:** 768–73.
22. Gauldie J, Richards C, Harnish D, Lansdorp P, Bauman H. Interferon beta 2/B-cell stimulatory factor 2 shares identity with monocyte derived hepatocyte-stimulating factor and regulates the major acute phase protein response in liver cells. *Proc Natl Acad Sci USA* 1987; **84:** 7251.

Maternal relaxin concentrations in diabetic pregnancy

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Maternal serum concentrations of relaxin, an insulin homologue produced both by the corpus luteum of pregnancy and by the fetoplacental unit, are highest in the first trimester and fall to their lowest level in the third trimester. Relaxin is thought to influence carbohydrate metabolism in the uterus, and it has been suggested that serum concentrations of relaxin in diabetic women are higher than those of non-diabetic women.

We show that maternal serum relaxin concentrations are significantly higher at each stage of pregnancy in insulin-dependent diabetic mothers than in non-diabetic mothers. This elevation in relaxin concentrations is not related to other indices of diabetic control. The physiological importance of the higher concentrations of relaxin in the serum of diabetic women—in particular, whether they contribute to the higher incidence of major anomalies in the fetuses of diabetic mothers—is yet to be determined.

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