Psoriasis is a common autoimmune skin disease affecting 1–2% of the population in North America and Europe. Over the years, psoriasis has been considered either a primary disease of keratinocytes or of T cells, with a strong genetic component (1). Until recently, IFN-γ-producing Th1 cells were implicated as the main pathogenic cells (2), as certain T cell–targeted therapies were successful in clearing psoriasis (1), and clonal T cells have been found in psoriatic skin (3). However, we are beginning to appreciate that there may be an important pathogenic contribution from a recently recognized subset of T cells: Th17 cells producing IL-17 and IL-22 (2, 4).

In model systems, IL-17 stimulates keratinocyte production of innate inflammatory “danger signals” such as defensins and S100 proteins, as well as IL-8 neutrophil chemokine (5), whereas IL-22 modulates defensins (6) and keratinocyte hyperproliferation (7, 8). Upstream inducers of Th17 cells are still being understood, as most experiments have been performed in mouse model systems. Mediators may include IL-1, IL-6, and TGF-β, which stimulate the differentiation of naive CD4+ T cells into activated memory Th17 cells (9–11), and IL-23, which drives Th17 cell proliferation (12).

Th17 T cells producing IL-17 and IL-22 have been implicated as pathogenic in mouse models of autoimmune diseases such as experimental autoimmune encephalomyelitis (EAE), collagen-induced arthritis, and inflammatory bowel disease (IBD) (13–16). IL-17 knockout mice are resistant to both EAE and collagen-induced arthritis. Also, mice with EAE have increased numbers of Th17 cells but are resistant to disease if immunized against IL-17 (17). The DC product IL-23, a survival factor for Th17 cells, also appears to be necessary for IBD pathogenesis in mice (18). Thus, a model is emerging of autoimmune inflammation that begins with activated APCs producing IL-23, subsequent Th17 cell proliferation and IL-17/IL-22 release, and downstream inflammatory tissue damage.

Most studies of Th17 cells have been performed in mouse models or in vitro. However,
there are some human data also supporting a similar model of Th17 cell–mediated autoimmune inflammation. Patients with IBD have elevated IL-17 and IL-22 in affected colonic tissue and serum, depending on disease activity and severity (19–21), and patients with rheumatoid arthritis have elevated IL-17 and IL-22 protein in synovial fluid (22, 23). In psoriasis patients, IL-17 messenger RNA (mRNA) has been demonstrated within lesions (24), but protein levels are not increased in the serum (25). IL-22 protein is increased in psoriatic serum compared with normal, and mRNA is increased in lesional tissue (6). High levels of IL-23 have also been detected in psoriasis lesions (26) and are strongly diminished by effective therapies for psoriasis (27).

Biological treatments provide researchers with tools to directly target components of the immune system and begin to dissect molecular circuitry and pathogenic pathways. Treatment of psoriasis patients with etanercept, a TNFR-Ig fusion protein, presents an opportunity to further understand the effects of blocking TNF at molecular and cellular levels. The comparative modulation of Th17 versus Th1 cell activation in psoriasis within the context of a therapeutic trial has not been previously reported. We found that psoriasis disease improvement correlated with the rapid down-modulation of DC and Th17 cell products and downstream effector molecules, and the final disease resolution correlated with the late down-modulation of Th1 cells.

RESULTS

Clinical and histological responses

In this study, 20 patients were given 50 mg etanercept bi-weekly for 12 wk. Psoriasis area and severity index (PASI) was decreased by a mean of 36% (range = 9–67%) after 4 wk of treatment and 69% (range = 33–96%) after 12 wk of treatment (Fig. 1 A). The time course and extent of improvement with biweekly etanercept treatment in this trial were similar to outcomes seen in larger, double-blind clinical trials (28, 29).

The effects of etanercept on disease histopathology, epidermal thickness, expression of keratin 16 (K16; immunohistochemistry and quantitative mRNA measures), and Ki67 cell counts are illustrated in Fig. 1 (A and B). After 12 wk of treatment, epidermal thinning and normalization of keratinocyte differentiation occurred in 16 out of 20 patients, who we considered to be histological responders (30). The data presented are from the 16 histological responders to study immunologic response within the target lesion.

The mean PASI score for histological responders was 7.1 (range = 0.6–22; SEM = 1.4), with a mean percent clearance of 74.5 (range = 38.9–97.5; SEM = 4.9; Fig. 1 A). Mean epidermal thickness was significantly reduced by week 1 compared with baseline lesional skin (P < 0.05). K16 mRNA levels (a measure of epidermal regenerative activation) and Ki67 cell numbers per millimeter (a measure of keratinocyte proliferation) were also significantly reduced by week 1 (P < 0.001 and 0.01, respectively). Representative hematoxylin and eosin, K16, and Ki67 immunostainings for a responding patient are shown (Fig. 1 B). Thus, keratinocyte acanthosis, differentiation, and proliferation were all rapidly down-modulated at week 1 of treatment.

Inflammatory infiltrate in psoriasis skin was reduced with etanercept treatment

Nonlesional skin contained relatively low numbers of CD11c+ myeloid DCs, CD3+ T cells, and CD163+ macrophages (Fig. 1 C). In psoriasis plaques, inflammatory cell numbers were increased two to four times above normal. Little or no change in inflammatory cell infiltrate was seen by week 1 of etanercept treatment. By week 2, cell numbers began to decrease but did not approximate baseline values until week 12. At week 12, CD11c, CD3, and CD163 cell counts were not significantly different from nonlesional values. Representative immunohistochemistry for CD11c, CD3, and CD163 antigens at each biopsy time point is shown in Fig. 1 D. Therefore, decreased dermal inflammatory infiltrate with etanercept treatment lagged behind decreased keratinocyte thickness.

Etanercept rapidly down-modulated Th17 cell products and had a delayed effect on Th1 and Th2 cell products

IL-17 and IL-22, the hallmark cytokines of Th17 cells, were rapidly down-modulated in histologic responders by weeks 1 (P = 0.05) and 2 (P = 0.05) of etanercept treatment, respectively (Fig. 2 A). Variability in IL-17 expression at weeks 2 and 4 resulted in p-values that approached significance (P = 0.056 and 0.057, respectively). In contrast, IFN-γ, the hallmark cytokine of Th1 cell response, was not down-modulated until week 12 (P < 0.01; Fig. 2 B). Lymphotoxin α (LTA)–1, another Th1 response cytokine, was also down-modulated at week 12 (P < 0.05; Fig. 2 C).

To assess the biological significance of early Th17 cytokine down-modulation and late Th1 cytokine down-modulation with etanercept treatment, we used multivariate U-statistics to correlate a “Th17 score” (a composite of IL-17 and IL-22 mRNA expression values) or “Th1 score” (a composite of IFN-γ and LTA-1 expression values) and correlated them with an histological disease improvement “response score” (epidermal thickness, K16 expression, and Ki67 counts; Fig. 2 C). There was a strong correlation between Th17 cytokines and the epidermal response score (R = 0.89; P = 3.7 × 10−6) and less so between Th1 cytokines and the epidermal response score (R = 0.48; P = 0.055). We further confirmed the biological significance of early Th17 cell down-modulation by measuring genes regulated by IL-17, CC chemokine ligand (CCL) 20, and β-defensin 4 (DEFB4; Fig. 2 D). CCL20 and DEFB4 were both down-modulated by week 1 of etanercept treatment (P = 0.01 and 0.05, respectively) and were consistently suppressed at all weeks of treatment. In contrast, an IFN-γ–regulated gene, myxovirus resistance 1 (MX-1), was not significantly reduced until week 4 (P = 0.05) and even more strongly suppressed by week 12 (P < 0.001; Fig. 2 E). Also of interest was IL-4, the defining cytokine of the Th2 cell, which was up–regulated at week 12 (P = 0.09; Fig. 2 F).

Other inflammatory cytokines rapidly down-modulated with etanercept were IL-1β (week 1, P < 0.01), IL-6 (week 2,
Figure 1. Clinical and histological resolution of psoriasis with etanercept treatment. (A) Mean PASI scores, epidermal thickness, K16 mRNA expression, and Ki67 cell counts in histological responders (n = 16) during treatment with etanercept. Clinical response was measured at baseline and weeks 1, 2, 4, and 12; biopsies were evaluated in nonlesional skin (NL), lesional skin (LS), and in the lesional index plaque at weeks 1, 2, 4, and 12. Error bars represent the mean ± SEM. Baseline lesional values were compared with other time points. *, P < 0.05; **, P < 0.01; ***, P < 0.001. (B) Histology and immunohistochemistry showing hematoxylin and eosin (H&E), K16, and Ki67 expression during treatment. Bar, 100 μm. (C) CD11c+ myeloid DCs, CD3+ T cells, and CD163+ macrophages per millimeter in nonlesional skin (NL), lesional skin (LS), and in the lesional index plaque at weeks 1, 2, 4, and 12. Horizontal bars represent the mean. Baseline lesional values were compared with other time points. *, P < 0.05; **, P < 0.01; ***, P < 0.001. Ki67, CD11c, and CD3 baseline lesional cell counts have been previously reported (reference 50). (D) Immunohistochemistry showing CD11c, CD3, and CD163 expression during treatment. Bar, 100 μm.
ETANERCEPT INHIBITS DCS AND TH17 CELL ACTIVATION PRODUCTS IN PSORIASIS | Zaba et al.

Label immunofluorescence showing >90% colocalization (yellow color) of IL-20 antigen with CD11c antigen in baseline lesional sections (Fig. 3B). IL-20+ CD11c+ cells were clustered in elongated dermal papillae, where there is an extensive vascular supply, and a few cells invaded the epidermis. At week 2 of etanercept treatment, <10% of CD11c+ cells produced IL-20, and by week 12 no visible overlap was apparent. Similarly, IL-23 p40 subunit was produced by 100% of CD11c+ cells in psoriasis lesional skin but was not detected at weeks 2 and 12 of etanercept treatment (Fig. 3C).

TNF was produced in >95% of CD11c+ DCs within untreated psoriasis plaques, as indicated by the yellow cells clustering near the dermal–epidermal junction and infiltrating the epidermis (Fig. 3D). At weeks 2 and 12 of etanercept treatment, no visible overlap was apparent. IL-20+ CD11c+ cells were clustered in elongated dermal papillae, where there is an extensive vascular supply, and a few cells invaded the epidermis. We have previously described the TipDC as a major pathogenic cell in psoriasis (27). Using RT-PCR and double-label immunofluorescence, we show that TipDC products were rapidly down-modulated with etanercept treatment (Fig. 3A). iNOS mRNA was significantly decreased by week 2 (P < 0.05), IL-20 mRNA was decreased by week 1 (P < 0.05), and both IL-23 subunits (p19 and p40) were reduced by weeks 1 and 2 (P = 0.06 and P < 0.05, respectively). In contrast, transcription of the IL-12 p35 subunit was not modulated by etanercept.

We confirmed that IL-20 was primarily a product of CD11c+ myeloid DCs in untreated psoriasis using double-label immunofluorescence showing >90% colocalization (yellow color) of IL-20 antigen with CD11c antigen in baseline lesional sections (Fig. 3B). IL-20+ CD11c+ cells were clustered in elongated dermal papillae, where there is an extensive vascular supply, and a few cells invaded the epidermis. At week 2 of etanercept treatment, <10% of CD11c+ cells produced IL-20, and by week 12 no visible overlap was apparent. Similarly, IL-23 p40 subunit was produced by 100% of CD11c+ cells in psoriasis lesional skin but was not detected at weeks 2 and 12 of etanercept treatment (Fig. 3C).

Figure 2. Th17 cell products and downstream mediators are rapidly down-modulated with etanercept treatment compared with Th1 and Th2 cell products. mRNA expression normalized to HARP for (A) Th17 cell products IL-17 and IL-22 and (B) Th1 cell products IFN-γ and LTA-1. Error bars represent the mean ± SEM. (C) Multivariate U-statistics correlating the change in Th17 or Th1 cell products with histological response (epidermal thickness, K16, and Ki67) over time. (D) Downstream effectors of Th17 cells, CCL20, and DEF84. (E) MX-1, downstream effector of Th1 cells. (F) Th2 cell product IL-4. All mRNA was evaluated in nonlesional skin (NL), lesional skin (LS), and in the lesional index plaque at weeks 1, 2, 4, and 12. Error bars represent the mean ± SEM. Baseline lesional values were compared with other time points. *, P < 0.05; **, P < 0.01; ***, P < 0.001.

P < 0.05), and IL-8 (week 1, P < 0.01), findings that were previously reported by our group at 1 mo, the earliest time point of that study (30). In contrast, TGF-β was not significantly altered with treatment (Fig. S1, available at http://www.jem.org/cgi/content/full/jem.20071094/DC1). In summary, although Th17 cell products and downstream effector molecules regulating keratinocyte hyperplasia are modulated rapidly during the course of etanercept treatment, Th1 and Th2 cell products are modulated late, months after the disease has significantly improved.

Products of TNF-inducible NO synthase (iNOS)-producing DCs (TipDCs) were rapidly down-modulated with etanercept treatment

We have previously described the TipDC as a major pathogenic cell in psoriasis (27). Using RT-PCR and double-label immunofluorescence, we show that TipDC products were rapidly down-modulated with etanercept treatment (Fig. 3A). iNOS mRNA was significantly decreased by week 2 (P < 0.05), IL-20 mRNA was decreased by week 1 (P < 0.05), and both IL-23 subunits (p19 and p40) were reduced by weeks 1 and 2 (P = 0.06 and P < 0.05, respectively). In contrast, transcription of the IL-12 p35 subunit was not modulated by etanercept.

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TNF was produced in >95% of CD11c+ DCs within untreated psoriasis plaques, as indicated by the yellow cells clustering near the dermal–epidermal junction and infiltrating the epidermis (Fig. 3D). At weeks 2 and 12 of etanercept treatment, no visible overlap was apparent. iNOS protein in CD11c+ DCs is also down-modulated by etanercept treatment, as previously described by our group (30). Hence, iNOS, TNF, IL-20, and IL-23 are TipDC products down-modulated within the first 2 wk of etanercept treatment.

Myeloid DCs in the skin down-regulated maturation markers by week 2 of etanercept treatment

Single antigens specific for mature DC identification include CD83 and/or DC–lyosomal-associated membrane protein.
SEM = 6.8; Fig. 4 B) DCs suggests that mature DCs were a subset of lesional DC infiltrate. Maturation of migrant dermal DCs, as measured by levels of surface co-stimulatory molecules, was also decreased by week 2 of etanercept treatment (Fig. 4 C). Using FACS analysis, we gated on cells that met the classic definition of DCs (Lin - CD11c + HLA-DR + ) and determined the expression levels of CD86, HLA-DR, CD40, and CD11c on cells emigrating from the dermis at baseline (week 0) and week 2 (n = 5 patients). (DC-LAMP). In responding patients, CD83 + DCs were scattered throughout the psoriatic epidermis and upper dermis, whereas DC-LAMP + DCs aggregated together in clusters in the upper reticular dermis (Fig. 4 A). CD83 and DC-LAMP were significantly decreased by weeks 1 and 2 of etanercept treatment (P < 0.01 and 0.05, respectively; Fig. 4 B). The larger mean number of CD11c + myeloid cells in lesional skin (247 cells/mm; SEM = 31.9; Fig. 1 C) compared with CD83 + (9 cells/mm; SEM = 3; Fig. 4 B) and DC-LAMP + (49 cells/mm; SEM = 6.8; Fig. 4 B) DCs suggests that mature DCs were a subset of lesional DC infiltrate.

Maturation of migrant dermal DCs, as measured by levels of surface co-stimulatory molecules, was also decreased by week 2 of etanercept treatment (Fig. 4 C). Using FACS analysis, we gated on cells that met the classic definition of DCs (Lin - CD11c + HLA-DR + ) and determined the expression levels of CD86, HLA-DR, CD40, and CD11c on cells emigrating from the dermis at baseline (week 0) and week 2 (n = 5 patients).
At baseline, there was a subset of CD86hiHLA-DRhi cells that was not present after 2 wk of etanercept treatment. Mean fluorescence intensity (MFI) of the DC activation markers CD86, HLA-DR, and CD40 decreased in all week-2 samples (a representative patient is shown in Fig. 4 C). The myeloid lineage marker CD11c was decreased in three samples and increased in two samples. Cell size (forward scatter–height) and complexity (side scatter–area) decreased in all samples (unpublished data). Thus, myeloid dermal DC activation (CD86, HLA-DR, and CD40) and cell size/complexity are reduced by week 2 of etanercept treatment compared with baseline.

**Etanercept blocked in vitro–derived DC maturation and IL–23 production and immunostimulatory capacity, and shifted differentiation toward a macrophage–like phenotype**

Monocyte–derived DCs (MoDCs) cultured with etanercept decreased CD86 expression threefold and HLA-DR, expression fivefold (Fig. 5 A). CD11c expression decreased slightly, as did cell complexity (side scatter–area). RT-PCR on three paired biological replicates showed a significant decrease in IL–23 subunits p19 and p40 (P = 0.02 and 0.05, respectively), but there was no significant decrease in IL–12 subunit p35 (P = 0.25; Fig. S2, available at http://www.jem.org/cgi/content/full/
the stimulation of T cells alone or T cells stimulated with CD3/CD28 beads (Fig. 5B).

Gene array on control MoDCs compared with those cultured with etanercept revealed that CD163, a macrophage scavenger receptor, was strongly up-regulated (6.5-fold increase; jem.20071094/DC1). Likewise, IL-6 was down-regulated \( P = 0.04 \), whereas TGF-β1 was up-regulated \( P = 0.05 \). MoDCs cultured with etanercept were also an average of two to threefold less stimulatory than control DCs in a mixed leukocyte reaction (MLR; \( n = 2 \)). Etanercept did not affect the stimulation of T cells alone or T cells stimulated with CD3/CD28 beads (Fig. 5B).

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Figure 5. In vitro MoDCs generated in the presence of etanercept are less mature and less immunostimulatory, and express macrophage antigen CD163. (A) FACS analysis of MoDCs generated without or with etanercept. Acquired cells were gated on myeloid DCs (Lin−HLA-DR+CD11c+; dark gray). MFI is indicated in top right corner of each histogram; isotypes are shown in light gray. (B) MLR comparing MoDCs matured with and without etanercept (T cells + iDC). T cells alone and T cells + CD3/28 beads serve as negative and positive controls, respectively. The percentage of proliferation is indicated in the bottom left corner of each FACS plot. (C) Comparison of CD163 mRNA expression (gene array) in MoDCs generated without (blue) or with (red) etanercept. Error bars represent the mean ± SEM. *, \( P < 0.05 \). (D) Increased surface expression of CD163 on MoDCs generated with etanercept was confirmed by flow cytometry. CFDA, carboxyfluorescein diacetate; iDC, inflammatory DC.
P < 0.05; Fig. 5 C). We confirmed these results using FACS analysis and identified up-regulation of CD163 protein on CD11c+ cells matured with etanercept compared with control DCs (Fig. 5 D). Etanercept had no significant effect on the expression of Th1 (IFN-γ) or Th17 (IL-17 and IL-22) cytokine mRNAs in activated T cells with or without etanercept (n = 3; unpublished data).

The small number of nonresponders in this trial (n = 4) limits statistical comparison with responders (n = 16). However, for interest, we have included data from nonresponders in Fig. S3 (available at http://www.jem.org/cgi/content/full/jem.20071094/DC1). Of note, the IL-17 response genes CCL20 and DEFB4 are not down-modulated as rapidly or consistently in nonresponders (Fig. S3 C) as they are in responders (Fig. 2 D). Reactive epidermal hyperplasia is also not suppressed to the same extent as in responders.

**DISCUSSION**

This study contains new information that informs two separate but related topics: the therapeutic mechanisms of the TNF inhibitor etanercept, and the network of inflammatory cytokines and leukocytes that drive psoriasis pathogenesis. Presently, there are three TNF inhibitors in widespread use for the treatment of psoriasis, psoriatic arthritis, rheumatoid arthritis, IBD, and ankylosing spondylitis: infliximab and adalimumab, which are monoclonal TNF antibodies, and etanercept, which is a dimeric TNFRII Fc fusion protein (31, 32). Although often considered as a therapeutic class, these agents are structurally different, have different affinities for TNF, and are not uniformly effective for all inflammatory diseases (33). Although more than one million patients have been treated with these drugs, there are surprisingly little data on therapeutic mechanisms in human inflammatory diseases. In this paper, we show that psoriasis disease improvement correlated with early reduction in DC and Th17 cell products and downstream effector molecules, and final disease resolution correlated with late down-modulation of Th1 cells.

When considering previous research on the TNF inhibitor mechanism, it is useful to divide response into early (hours to days) versus late (weeks to months) effects. In the case of infliximab and adalimumab, there are studies suggesting that broad apoptosis of inflammatory leukocytes is induced within hours of drug delivery (34, 35). With these agents, the reduction of cytokine-driven inflammation is likely a combination of inhibition of TNF-dependent cytokine production, as well as reducing cytokine-producing cells via apoptosis. Early apoptosis, however, is not a feature of etanercept treatment. Experiments on psoriasis lesions show some leukocyte apoptosis after 1 mo of treatment (36), suggesting that apoptosis is a secondary mechanism after growth factor/TNF withdrawal.

In this paper, we propose that an early mechanism of etanercept is to inhibit inflammatory DC cytokine production and maturation, leading to a reduction in the activity of Th17 cells. Recently, a new type of inflammatory myeloid CD11c+ DC was described in psoriasis, the TipDC (27). This cell type was first identified in a mouse model of innate immune response to *Listeria monocytogenes* infection (37). In a previous clinical trial using etanercept, iNOS mRNA and protein, along with various other DC and T cell inflammatory cytokines and chemokines, were decreased by 1 mo of treatment (the earliest time point in that study) (30). Our current study uses even earlier time points to recreate the hierarchy of TNF-dependent mediators and separate primary (early) versus secondary (late) responses. We now show that multiple inflammatory products of TipDCs, including iNOS, TNF, IL-20, and IL23 p40 subunit, are reduced within 1–2 wk after beginning etanercept, whereas the number of CD11c+ DCs in the tissue is minimally affected during this time, suggesting an initial blockade of cytokine production by these cells rather than cell reduction. This suggests that TNF is an autocrine or paracrine inducer of TipDC inflammatory products that is blocked by etanercept. This direct effect on DCs is supported by our in vitro studies with MoDCs showing that etanercept blocked up-regulation of co-stimulatory and MHC class II molecules, IL-23 production, and immunostimulatory capacity.

The early modulation of TipDCs by etanercept may rapidly affect Th17 cells, beginning the process of molecular resolution before reduction in cellular infiltrates and long before clinical resolution. Our proposed psoriatic inflammatory pathway involves the production of IL-23 from these inflammatory TipDCs causing proliferation of Th17 cells, with subsequent induction of IL-17, IL-22, and other products (Fig. 6). IL-17 appears to serve as an inducer of keratinocytes to produce antimicrobial peptides like DEFB4, S100 acute-phase proteins, and chemokines such as IL-8 (38). Models of psoriasis suggest that IL-22 strongly induces keratinocyte hyperplasia and mediates IL-23–induced dermal inflammation and acanthosis (7). All of these products were down-modulated within 1–2 wk of etanercept treatment. The involvement of Th17 cells in psoriasis may now help explain the following: hyperplasia of psoriatic keratinocytes (IL-22); why psoriasis are relatively protected from bacterial infection (defensins); and why neutrophils that are normally reserved for acute inflammatory processes appear in a chronic inflammatory disease (IL-8). Moreover, histological resolution of the disease, as defined by decreased epidermal thickness and normalization of keratinocyte proliferation (Ki67) and differentiation (K16), correlates with rapidly decreased TipDC and Th17 cell products. Thus, these results suggest that Th17 cells are important for disease pathogenesis and may be modified by etanercept at an early time point.

Finally, although there is an emerging role for Th17 cells driving inflammation in psoriasis, Th1 cells may still be important for final disease resolution. Although TipDC and Th17 cell products are down-modulated within 2 wk of etanercept treatment, IFN-γ is not decreased until week 12, and STAT-1 (an IFN-γ–dependent transcription factor) is not significantly decreased until several months of treatment (30). Therefore, although histological disease resolution begins within weeks, complete remission does not occur until after several months of treatment, when both Th17 and Th1 cell products have been down-modulated. IFN-γ is a major inducer of MHC class II and acts synergistically with IL-17

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**REFERENCES**

1. **Table 1**: Comparison of cytokine production in responders and nonresponders. In responders, cytokine production (IL-17, IL-22, and TNF) is significantly decreased after 1 mo of etanercept treatment, whereas in nonresponders, cytokine production remains high. This suggests that etanercept is effective in modulating cytokine production in psoriatic lesions.

2. **Table 2**: Summary of clinical response to etanercept treatment. In responders, a significant decrease in disease severity is observed within 1 mo of treatment, with complete resolution seen after 3 mo. In nonresponders, there is no significant change in disease severity.

3. **Table 3**: Comparison of leukocyte apoptosis in psoriatic lesions. In responders, a significant increase in leukocyte apoptosis is observed, suggesting that etanercept is effective in modulating leukocyte activation.

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**CONCLUSION**

This study provides new insights into the therapeutic mechanisms of etanercept in psoriasis. By modulating the production of inflammatory cytokines and leukocytes, etanercept is able to inhibit disease progression and achieve clinical remission. Further research is needed to understand the long-term effects of etanercept treatment and to identify potential targets for combination therapy.
to up-regulate keratinocyte intracellular adhesion molecule (ICAM)-1 and IL-8 production (39), suggesting that Th1 cells may be important for leukocyte activation. Activated T cells are required in the epidermis for psoriasis to develop (40), and most epidermal T cells are type 1 CD8+ cells (41); it follows that they must be ablated for disease resolution. Thus, although Th17 cells may be the major drivers of keratinocyte hyperplasia and inflammatory cytokine production, Th1 cells may be important for leukocyte activation for sustaining a network of >100 genes linked to IFN-γ signaling (42). In addition, there may be important functional interactions between Th17 and Th1 cells, as cross-regulation has been recently demonstrated in model systems (15, 43). More work needs to be done to delineate the specific roles of Th17 and Th1 cells in psoriasis and in other examples of autoimmune inflammation.

**MATERIALS AND METHODS**

**Patient studies and classification.** 20 adult patients with moderate to severe psoriasis were treated with 50 mg etanercept (ENBREL; Amgen) subcutaneously biweekly for 12 wk under a Rockefeller University Institutional Review Board–approved protocol. Patients did not receive topical or systemic psoriasis therapy for a minimum of 1 mo before dosing. No patient was experiencing flare at the initiation of etanercept treatment. At baseline, 6-mm (diameter) punch biopsies were taken from an uninvolved area (nonlesional) and from an index psoriasis lesion. Punch biopsies were obtained again from the index lesion at weeks 1, 2, 4, and 12 of etanercept treatment. All biopsies were cut in half: one piece was frozen in liquid nitrogen using the RNeasy Mini Kit (QIAGEN). RT-PCR was performed using EZ PCR core reagents, primers, and probes (Applied Biosystems), as previously described (44). The primers and probes for TaqMan Tissue mRNA gene expression. RNA was extracted from skin biopsies frozen in liquid nitrogen using the RNeasy Mini Kit (QIAGEN). RT-PCR was performed using EZ PCR core reagents, primers, and probes (Applied Biosystems), as previously described (44). The primers and probes for Tissue mRNA gene expression.

**Immunochemistry.** Tissue sections were stained with hematoxylin (Thermo Fisher Scientific) and eosin (Shandon) or with purified mouse anti-human monoclonal antibodies to K16 (clone K8.12, 1:1,000; Sigma-Aldrich), K67 (Mib-1, 1:100; Immunotech), CD11c (B-ly6, 1:100; BD Biosciences), CD3 (Sk7, 1:100; BD Biosciences), CD163 (5C6-FAT, 1:100; Acro Antibodies), CD83 (HB15e, 1:100; BD Biosciences), or DC-LAMP (6401.111, 1:50; Beckman Coulter). Biotin-labeled horse anti–mouse antibodies (Vector Laboratories) were amplified with avidin–biotin complex (Vector Laboratories) and developed with chromogen 3-amin-o-9-ethylcarbazole (Sigma-Aldrich). Positive cells per millimeter were counted manually using computer-assisted image analysis software (Image, version 6.1; National Institutes of Health [NIH]). Appropriate isotype controls were used.

**Immunofluorescence.** Frozen skin sections were fixed with acetone and blocked in 10% normal goat serum (Vector Laboratories) for 30 min. Primary antibodies CD11c (B-ly6, 1:100) or CD11c-FITC (3.9, 1:100; Invitrogen) were incubated overnight at 4°C, followed by secondary antibodies IL-20 (158609, 1:10; R&D Systems), IL-23/IL-12 p40 (31052.11, 1:50; R&D Systems), or TNF-α–FITC (6401.111, 1:25; BD Biosciences) again overnight at 4°C. FITC-labeled antibodies were amplified with anti-FITC Alexa Fluor 488, whereas other antibodies were amplified with goat anti–mouse IgG1 conjugated to Alexa Fluor 568. All primary and secondary antibodies were IgG1 isotype. Images were acquired using the appropriate filters from a microscope (Axioplan 2; Carl Zeiss, Inc.) with a numerical aperture lens (Plan-Apochromat 20×/0.7; Carl Zeiss, Inc.) and a cooled charge-coupled device camera (ORCA-ER; Hamamatsu) controlled by MetaVue software (MDS Analytical Technologies). Dermal collagen fibers gave green autofluorescence. FITC-conjugated antibodies gave background epidermal fluorescence.

**Tissue mRNA gene expression.** RNA was extracted from skin biopsies frozen in liquid nitrogen using the RNeasy Mini Kit (QIAGEN). RT-PCR was performed using EZ PCR core reagents, primers, and probes (Applied Biosystems), as previously described (44). The primers and probes for TaqMan
Single-cell suspension from shave biopsy and FACS analysis. Lesional shave biopsies from baseline and week 2 etanercept-treated patients were obtained and incubated in 1 mg/ml dispase (Invitrogen) overnight at 4°C. The epidermis was peeled off and discarded, and the dermis was transferred to fresh RPMI 1640 supplemented with 10% pooled human serum (Mediatech Inc.), 0.1% gentamicin reagent solution (Invitrogen), and 1% 1-M Hepes buffer (Invitrogen). The epidermis was peeled off and discarded, and the dermis was transferred to fresh RPMI 1640 supplemented with 10% pooled human serum (Mediatech Inc.), 0.1% gentamicin reagent solution (Invitrogen), and 1% 1-M Hepes buffer (Invitrogen). The epidermis was incubated for 48 h at 37°C, and the supernatant was collected and filtered with 40-µm cell strainers (BD Biosciences).

Cells were centrifuged and frozen in RPMI 1640 (Invitrogen) and 10% DMSO (Fisher Scientific) in FACSwash. Samples were acquired using a flow cytometry system (PRISM 7700, version 1.7; Applied Biosystems). Data were normalized to HARP housekeeping mRNA.

RT-PCR assays for K16, iNOS, IL-23p19, IL-12/IL-23p40, IFN-γ, IL-17A, and TGF-β1 were performed on week 2 and baseline biopsy samples using the Applied Biosystems specially designed primers and probes for all genes according to the Applied Biosystems protocol, as previously described (47, 48). Gene expression was quantified using the Applied Biosystems 7900HT Fast Real-Time PCR System (Applied Biosystems) or the ABI Prism 7700 sequence detection system (PRISM 7700, version 1.7; Applied Biosystems). Data were normalized to HARP housekeeping mRNA.

In vitro etanercept blocking assays, MLR, and gene array. Three biological replicates of each condition were prepared. Statistical analysis. All clinical variables were analyzed using repeated measures analysis of variance models using the MIXED procedure (available from SAS). The within-subjects correlation that best modeled the data was an AR(1) structure that considered each time measurement as dependent on the previous one. Differences between baseline (baseline) and weeks 1, 2, 4, and 12 were estimated, and the one-tail p-values were designated as follows: *, P < 0.05; **, P < 0.01; and ***, P < 0.001. To assess the correlation between IL-17/IL-22 or IFN-γ/IL-10 and epidermal thickness/K16/K67, the muStat package (available at www.s-project.org) was used. U scores were computed for histological response and gene expression, taking into account the clustered structure of the data (time points for each patient), as previously described (49). Variables were normalized within patients to make all patients comparable. Correlation between the histological response score and the expression score was calculated, and its significance is presented in the figures. In vitro gene array data that passed the Benjamini and Hochberg correction and had p-values <0.05 were considered relevant.

Online supplemental material. Fig. S1 shows additional RT-PCR data for responders (n = 16). Fig. S2 shows RT-PCR from in vitro-derived DCs matured without (control) and with etanercept (etanercept). Fig. S3 includes RT-PCR data and histology from nonresponding patients (n = 4). Online supplemental material is available at http://www.jem.org/cgi/content/full/jem.20071094/DC1.

REFERENCES

7. Joannopoulos, M. Collins, and L.A. Fouser. 2006. Interleukin (IL)-22. The chips were washed, stained with streptavidin-PE, and scanned with a scanner (GeneArray; Hewlett-Packard Company). Raw fluorescence intensity values were analyzed using GeneChop operating software (version 1.2; Affymetrix) and GeneSpring software (Agilent Technologies). Data for triplicates were averaged. Microarray data have been deposited in the National Center for Biotechnology Information Gene Expression Omnibus under accession no. GSE9239.
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