Alteration of the Natural Killer Repertoire in H-2 Transgenic Mice: Specificity of Rapid Lymphoma Cell Clearance Determined by the H-2 Phenotype of the Target

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Summary

The mechanism behind natural tumor resistance conveyed by a H-2D\(d\) transgene to C57Bl/6 (B6) mice was investigated. Transgenic D8 mice were more efficient than control mice in natural killer (NK) cell mediated rapid elimination of intravenously inoculated radiolabeled lymphoma cells of B6 origin, such as RBL-5. There was no difference between D8 and B6 mice when elimination of YAC-1 targets was monitored. The effect of the transgene on the NK repertoire was related to the H-2 phenotype of the target: the differential elimination of RBL-5 lymphoma cells in D8 and B6 mice was not seen when a H-2 deficient variant of this line was used (efficiently eliminated in both genotypes), nor was it seen with a H-2D\(d\) transfectant (surviving in both genotypes). The data show that a MHC class I transgene can directly control natural killing in vivo by altering the repertoire rather than the general levels of NK activity. Since the NK mediated elimination seen after introduction of a novel gene in the host was neutralized by introducing the same gene (H-2D\(d\)), but not an unrelated class I gene (H-2D\(p\)), in the tumor, the data support the concept of NK surveillance against missing self. This combined transgenic/transfectant system may serve as a tool for a molecular dissection of the interactions between NK cells and their targets in vivo.

Several steps in immune responses are controlled by genes of the MHC. MHC class I and II genes educate, tolerize or activate the T cell subsets (1–5). There is also evidence for a MHC influence on NK cell function. F1-hybrid resistance mediated by natural killer cells against tumor and bone marrow grafts is one example (6–9). This phenomenon is poorly understood in comparison with the detailed knowledge of how MHC genes control the T cell system (1–5). It is not clear whether the genetic control of natural immunity involves the classical MHC genes, but natural resistance against lymphoma grafts has been mapped close to MHC class I genes in linkage studies (8, 9). We have reported that a H-2D\(d\) transgene introduced in C57Bl/6 (B6) mice convey natural resistance to lymphoma grafts of B6 origin (10). This resistance was dependent on the presence of NK cells, since it was abrogated by treatment of transgenic mice with mAbs against NK1.1 or heteroantiserum against asialo-GM1 (10).

The purpose of the present study was to investigate two aspects of this rejection. First, does the H-2D\(d\) transgene directly influence rapid NK mediated elimination, or is the transgene effect indirect, i.e., does it recruit NK cells as effectors in a later stage of a rejection response. Second, if the transgene affects natural killing directly, does it control the general levels of NK activity or the specificity pattern in their “repertoire”, i.e., killing of some but not all targets? In particular, is the H-2 phenotype of the target important?

We have studied these questions by following the early events after inoculation of radiolabeled lymphoma cells in transgenic and control mice. The clearance of 5'-[\(^{125}\text{I}\)]iodo-2'-deoxyuridine (\(^{125}\text{I}\)-IUdR) labeled cells has previously been used to measure NK activity in vivo (11–14). One advantage of this rapid assay is that it allows in vivo tests of natural resistance without the interference of the slower T cell mediated reactions against allogeneic or strongly immunogeneic tumors. Our results show that introduction of the H-2D\(d\) gene on B6 background affects early NK mediated elimination against some, but not all targets. Furthermore, the H-2 phenotype of the target appears to be crucial for the transgene effect, as shown most clearly in experiments with H-2 mutant and transfected subclones of the RBL-5 lymphoma.

Materials and Methods

Mice. Mice were bred and maintained at the Department of Tumor Biology, Karolinska Institutet. B6 mice were also purchased from ALAB (Sollentuna, Sweden). The generation of the transgenic

Abbreviations used in this paper: B6, C57Bl/6; \(^{125}\text{I}\)-IUdR, 5'-[\(^{125}\text{I}\)]iodo-2'-deoxyuridine.
DS strain has been described earlier (15). Briefly, a 8.0-kb EcoRI fragment from the plasmid pDd1 (16) containing the H-2D' gene was microinjected into fertilized B6 embryos and reimplanted into pseudopregnant B6 females. The expression and tissue distribution of the H-2D' gene paralleled that of the endogenous Kb and Db genes (17, 18). The DS strain was a kind gift from Dr. Gilbert Jay.

Tumors. H-2- tumors: RMA is a subline of the T cell lymphoma RBL-5. RMA-S is a H-2 deficient variant of RMA, generated by repeated cycles of negative selection using mouse allo anti-H-2b antisera and complement (19, 20). RMA-S has a defect in the association between the class I heavy chains and β2-microglobulin (β2m), resulting in a decreased expression of H-2 on the cell surface (21). RBL-5pDd1 and RBL-5DP are RBL-5 sublines transfected with the plasmids pDd1 (16) and pRM15 (22), respectively. EL-4 is a benzpyrene induced, and ALC a RAD-LV induced T cell leukemia. H-26 tumors: YAC-1 is a T cell lymphoma induced by Moloney Leukemia Virus in the A/Sn strain. A.H-2- is a β2m deficient variant of YAC-1 with no detectable cell surface expression of class I antigens (21, 22). H-24 tumors: L1210 is a T cell lymphoma and P815 is a mastocytoma, both induced by benzpyrene in the DBA/2 strain. All tumors were maintained as ascites lines in the syngeneic strain and explanted to in vitro culture 1–4 wk before experiments were carried out. Table 1 lists the different cell lines used in this study.

In Vivo Rapid Elimination Assay. Tumor cells (106/ml) were incubated over night in the presence of 0.5 μCi/ml of 5'-[12'I]iodo-2'-deoxyuridine (5'I-IdUdR; Amersham, Sweden AB, Solna, Sweden). Before inoculation, the radiolabeled cells were washed 3–4 times with large volumes of PBS and adjusted to 5 × 106/ml in PBS. The activity of the inoculation volume (106 cells in 200 μl) was determined and was usually in the range of 2–4 × 105 cpm. At different timepoints after inoculation, the mice were killed and the lungs, liver, and spleens removed. The remaining radioactivity in each organ was measured in a gamma counter and expressed as percentage of the total activity inoculated.

Pretreatment of Mice with Anti-NK1.1 Antibody. One day before inoculation of tumor cells, the mice were given one single injection of 200 μl ascites prepared anti-NK1.1 mAb (24). This treatment has previously been shown to abrogate natural killer cell activity in vivo (25).

Transfection. RBL-5 cells were electroporated together with the plasmid pDd1, encoding the Dd gene (16), or pRM15, coding for the Dd gene (22), in a BIO-RAD gene pulser (BIO-RAD, Richmond, California). Electroporation was carried out in 0.4 ml PBS at 250 Volts and 960 microFarads. After 10 min at room temperature the cells were put in RPMI with 10% FCS (normal culture conditions). When the number of surviving cells were 5–10 × 106, the dead and live cells were separated using Ficoll/hypaque (Pharmacia, Uppsala, Sweden) centrifugation, and subsequently sorted on a Fluorescence Activated Cell Sorter (FACS® 4; Becton Dickinson and Co., San Jose, California). In the case of Dd, cotransfection with the neomycin resistance gene was performed, and before sorting, a G418 resistant population was selected to enrich for clones expressing the class I gene. Cells were labeled with H-2Dd specific (34-4-8S, reference 26) or H-2DP specific (7-16.10, reference 27) mAb and positive cells were sorted on the FACS. After 4–5 such rounds of selection, stable transfectants were obtained that expressed H-2Dd or H-2DP in addition to the endogenous H-2Dd molecules. The resulting transfectants, RBL-5pDd1 and RBL-5DP were sensitive to H-2Dd and H-2DP specific CTL respectively, and they were both sensitive to H-2b specific allo CTL (not shown).

Indirect Immunofluorescence. 106 tumor cells were incubated with 100 μl of hybridoma supernatant 30–60 min on ice, washed with PBS, and incubated with 100 μl FITC conjugated rabbit anti-mouse Ig (Dakopatts, Hagersten, Sweden). After washing, the cells were analyzed on the FACS.

Statistical Analysis. Statistical calculations were performed using a two-tailed, non-paired t test. In cases where the variances between the groups were not comparable, the Cochran test was used.

Results

Survival of H-26 Lymphomas after Intravenous Inoculation to B6 and H-2Dd Transgenic Mice. Radiolabeled lymphoma

<table>
<thead>
<tr>
<th>Tumor cell</th>
<th>Parental tumor</th>
<th>Strain</th>
<th>Inducing agent</th>
<th>MHC class I haplotype</th>
<th>Transfected gene</th>
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<tbody>
<tr>
<td>RBL-5</td>
<td>-</td>
<td>C57Bl/6</td>
<td>Raucher virus</td>
<td>H-2d (KdDd)</td>
<td>(Dd)</td>
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<tr>
<td>RMA</td>
<td>RBL-5</td>
<td>C57Bl/6</td>
<td>Raucher virus</td>
<td>H-2d (KdDd)</td>
<td>(Dd)</td>
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<tr>
<td>RMA-S</td>
<td>RBL-5</td>
<td>C57Bl/6</td>
<td>Raucher virus</td>
<td>H-2d (KdDd)</td>
<td>(Dd)</td>
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<tr>
<td>RBL-5pDd1</td>
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<td>Raucher virus</td>
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<tr>
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<td>-</td>
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<td>-</td>
<td>C57Bl/6</td>
<td>RAD-LV</td>
<td>H-2d (KdDd)</td>
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<tr>
<td>YAC-1</td>
<td>-</td>
<td>A/Sn</td>
<td>Moloney virus</td>
<td>H-2d (KdDd)</td>
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<tr>
<td>A.H-2-</td>
<td>YAC-1</td>
<td>A/Sn</td>
<td>Moloney virus</td>
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<td>(Dd)</td>
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<tr>
<td>P815</td>
<td>-</td>
<td>DBA/2</td>
<td>Methylcholantrene</td>
<td>H-2d (KdDd)</td>
<td>(Dd)</td>
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<tr>
<td>L1210</td>
<td>-</td>
<td>DBA/2</td>
<td>Methylcholantrene</td>
<td>H-2d (KdDd)</td>
<td>(Dd)</td>
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* Weak but detectable expression.

Table 1. Cell Lines Used in this Study
cells were inoculated into B6 and D8 mice. Survival of inoculated cells was estimated by measuring remaining radioactivity in different organs at different time points. There was a significant difference in pulmonary clearance of RBL-5 lymphoma cells between control B6 and transgenic D8 mice at 12 h after inoculation. The same pattern was seen in the liver, while there was a marginal difference in the spleen (Fig. 1 A). The terms clearance or elimination will be used for this difference in endpoint survival of lymphoma cells, since kinetic studies (further discussed below) showed that there was no difference in homing patterns of lymphoma cells in the different genotypes of mice. To study whether this differential elimination was a general phenomenon or unique to RBL-5, we inoculated two other lymphomas with high H-2b expression, ALC and EL-4. The same selective elimination in the D8 mice was seen also for these lymphomas (Fig. 1 B).

Target Cell Specificity of the Transgene Effect. In contrast to the H-2b lymphomas, YAC-1 cells were eliminated equally efficiently in B6 and D8 mice at 12 h (Fig. 2 A). YAC-1 is known to be efficiently killed by NK cells within hours in vitro as well as in vivo (14). It was possible that the 12-h time point was suboptimal to detect a H-2Dd mediated difference in clearance, but we failed to observe any difference in survival in assays after 3 h (Fig. 2 B). The previously known genetic differences in NK activity between A/Sn (low), B6 (intermediate) and CBA (high) (14) were readily detectable at this time point.

The L1210 lymphoma and P815 mastocytoma, both of DBA/2 (H-2b) origin, gave the same pattern as YAC-1. They were equally well eliminated in D8 and B6 mice, whether tested after 3 (P815, Fig. 3 A), 12 (P815, Fig. 3 B) or 21 (L1210, Fig. 3 C) h. RMA (Fig. 3 B) or RBL-5 (Fig. 3 C) were included as a control for transgene induced elimination. Expression of H-2Dd was a common feature for the three tumors for which there was no difference in elimination between control and transgenic mice. To test whether the lack of transgene effect on clearance of YAC-1 cells was dependent on the H-2Dd product (or class I expression in general) at the tumor cell level, we inoculated cells from the YAC-1 variant line A.H-2-. This line does not express any class I gene products at the cell surface due to a translational block of the β2m mRNA (21, 22). Nevertheless, this cell was equally well eliminated from D8 and B6 mice (Fig. 4). The
Figure 3. Remaining radioactivity in the lungs of B6 and D8 mice for P815 (A), RMA and P815 (B) and RBL-5 and L1210 (C). For each experiment, the different timepoints are indicated in parentheses. Data for RMA to D8 in (B) was obtained from three mice. The differences between B6 and D8 for RMA (p < 0.01 in Fig. 3 B) and RBL-5 (p < 0.001 in Fig. 3 C) were statistically significant.

Figure 4. Elimination of H-2 negative YAC-1 variant A.H-2-. The figure shows remaining radioactivity in the lungs of B6, D8, CBA and A/Sn mice 3 h after inoculation. Mean of two experiments. The difference between A/Sn and CBA was significantly different (p < 0.01).

Figure 5. Effect of anti-NK1.1 treatment on 12-h survival of RMA and H-2 deficient variant RMA-S in the lungs of B6 and (D8 x B6)F1 mice. In this experiment all data for B6 and data for RMA-S in untreated (D8 x B6)F1 were obtained from groups of three mice. The difference between B6 and (D8 x B6)F1 for RMA was statistically significant (p < 0.001).

Figure 6. Remaining radioactivity (after 12 h) of normal, H-2Dd transfected RBL-5 or H-2Dd transfected RBL-5 in the lungs of B6 and D8 mice. The figure is a summary of two independent experiments. The number of mice in each host/tumor combination was 8 except for RBL-5 to B6 where 9 mice were used. The difference between B6 and D8 was statistically significant for RBL-5 (p < 0.05) and RBL-5Dd (p < 0.001), but not for RBL-5pDd1. Just before the experiments, the transfected cells were analyzed for the expression of the transfected genes, as described in materials and methods. Fluorescence values (lin) from a representative analysis were for Kb, Db, Dd, DP and no antibody respectively: RBL-5 (353, 453, 24, 12, 13), RBL-5pDd1 (267, 312, 217, n.d., 15) and RBL-5Dd (310, 370, n.d., 147, 11). n.d., = not determined.
lymphoma; it should now survive in both hosts. To test this, the RBL5 lymphoma was transfected with the H-2Dd gene. When the resulting transfectant (RBL5pDd1) was used, the selective elimination in the D8 mice was abrogated (Fig. 6). As a control, RBL5 was transfected with the H-2Dp gene and used in the same experiments. For this transfectant the pattern of elimination was similar to that of untransfected RBL5.

H-2 Transgene in the Host Versus H-2 Deficiency in the Target. Kinetics and Organ Distribution of Clearance in Two Different Situations. The survival of RBL5 in B6 mice at different time points was used as a control for elimination caused by the H-2Dd transgene in the host (comparison with RBL5 into (D8 × B6)F1) or D8 elimination caused by the H-2 deficiency of the target (comparison with RMA-S into B6). Neither comparison revealed any significant differences at 15 min or 4 h after inoculation (Fig. 7 A–C). However, at 12 h, a significant difference between B6 and (B6 × D8)F1 (Fig. 7 A, Exp. 1), or between B6 and D8 (Fig. 7 D, Exp. 2) in the ability to eliminate RMA was seen in the lungs. In the same comparison, there was also a significantly better elimination of RMA-S than of RMA in normal B6 mice (Fig. 7, A and D). In all cases this difference was more pronounced than the difference between RMA in B6 and transgenic mice. The differences were smaller in the liver and could not be seen in the spleen (Fig. 7 B, E, C, and F).

Discussion

Our results indicate a direct influence of a MHC transgene on rapid elimination of tumor grafts mediated by NK cells. This extends previous studies with MHC congenic mice, where elimination within 4–36 h after inoculation of radiolabeled cells has been shown to be T cell independent (11–13). Another main conclusion is that the transgene effect varied depending on the target cell, i.e., it affected the repertoire rather than general levels of killing. The effect of the transgene could be seen against several lymphomas of H-2b background, but could not be detected against three allogeneic lymphomas (P815, L1210, and YAC-1), nor against a completely H-2 negative lymphoma variant (A.H-2−) and a H-2 deficient mutant of the H-2b lymphoma RBL5 (RMA-S). We interpret this as a consequence of efficient natural killing of these cells in control as well as in transgenic mice, rather than absence of NK effects in both genotypes. The recovered levels of radioactivity were low and YAC-1, L1210, and RMA-S
are known to be efficiently cleared by NK cells in B6 and B10 mice (11, 13, 14, 28). Efficient NK-mediated elimination of RMA-S in both (D8 × B6)F1 and B6 mice was also demonstrated directly by the use of host treatment with anti-NK1.1 mAb (Fig. 5).

Why was the elimination efficient against some cells in normal B6 mice, while other targets were killed only in the B6 mice carrying the H-2D4 gene? In previous studies, the match or mismatch of H-2 between host and target has been emphasized as an important factor contributing to rapid elimination (11, 13, 29). There were two possible explanations of the data in that respect: (a) Expression of a particular class I molecules on the target (e.g., H-2Dd, common for P815, L1210, and YAC-1) triggered the NK elimination in B6 as well as D8 mice, resulting in equally efficient elimination in both strains. (b) Complete H-2 class I mismatch between target and host (e.g., RBL-5 to B6) prevented elimination. Our data support the second alternative. The differences in elimination between D8 and B6 mice seen for tumor cells of the H-2b genotype could be abrogated by interfering with this effect, either by reducing endogenous H-2 expression in the lymphoma cells, or by introducing the “transgene” (H-2D4) in the lymphoma cells by transfection. In the former case efficient elimination occurred in both hosts, while in the latter lymphoma cells survived in both hosts. Thus, the H-2 match in the syngeneic (RBL-5 to B6) or “transsyngeneic” (RBL-5pD4 to D8) situation prevented elimination.

A recent survey of multiple host/donor combinations supports a role for self match in prevention of rapid elimination of grafted lymphocytes in the rat (30). However, also active recognition of allogeneic MHC by NK cells has been postulated in the rat (30, 31). It is unlikely that the allogeneic lymphomas in our study were actively recognized and eliminated in B6 mice because they expressed foreign MHC. The H-2 negative YAC-1 variant A.H-2- does not translate its β2m transcripts, and is therefore unable to express any class I molecules on the cell surface (21). Yet, it was at least as efficiently eliminated as YAC-1 in D8 and B6 mice. This showed that expression of H-2D4 (or any class I molecules) on the cell surface was not required for elimination. Furthermore, introduction of foreign MHC genes (H-2Dd or H-2Dp) did not result in increased elimination in B6 (Fig. 6). Thus, we find no evidence that allogeneic H-2 in the target cell can trigger a response. However, it must be noted that in bone marrow graft experiments, H-2D4 introduced as a transgene to B6 mice resulted in a NK-mediated rejection by non transgenic B6 mice (32). The reasons for this differential effect of H-2D4 on lymphoma and bone marrow cells are not known. One possibility is that the transgene suppresses expression of endogenous H-2Kβ, Dβ molecules in bone marrow but not in lymphoma cells, a possibility that is now being tested. Another possibility is that different subsets of NK1.1+ cells are active in marrow and lymphoma rejection. Recently, a CD3+ NK1.1+ cell has been shown to mediate marrow graft rejection (33). Our results do not distinguish between CD3+ NK1.1+ and CD3+ NK1.1+ as responsible effector cells. However, the latter are thymus dependent (33, 34), while the rapid elimination of H-2 mismatched lymphoma cells has been demonstrated also in nude mice (11).

The allogeneic tumors used in this study share one allele with the D8 mice, H-2D4, but none with B6. However, they did not survive better in H-2D4 positive D8 than in B6 mice. We propose that the partial match with respect to H-2D4 is insufficient to compensate for the lack of match with respect to H-2Kb and Dβ. A prediction from this is that H-2d cells, such as L1210, transfectcd with the relevant H-2d sequences should become resistant to elimination in both D8 and B6 mice.

A.H-2- showed differential sensitivity to elimination by CBA and A/Sn mice (Fig. 4), two strains with a known difference in levels of NK activity against YAC-1 (14). Since A.H-2- lacks MHC expression at the cell surface, it can be regarded as an “indicator” of NK activity, irrespective of match or mismatch between host and target MHC genotypes. Since there was no difference between D8 and B6 for A.H-2-, we conclude that the H-2D4 transgene has not altered the general levels of NK activity in the B6 strain.

Restoration of MHC class I expression by transfection has been reported to protect from NK lysis in several MHC deficient targets, even if this is not a general rule (reviewed in reference 35). The present study extends these findings by two original observations: (a) The transected gene protected from NK mediated elimination in vivo, and (b) The recipient line did not from the start have a primary general H-2 deficiency. Furthermore, we show that the protective effect was specific for a class I allele that corrected the transgene induced mismatch, since the control transfectant RBL-5pDp was not accepted in D8 mice. Presence of the H-2D4 transgene in D8 donor mice also led to protection of their bone marrow from rejection in H-2D4 expressing B10.D2 mice (32), although it was not formally shown that the protective effect of the transgene was exerted in the grafted cell, as in the present study. Conversely, bone marrow (reference 36, Högland, manuscript submitted for publication) and Con A induced T cell blasts (Högland, P., C. Öhlén, E. Carbone, L. Franksson, H.-G. Ljunggren, A. Latour, B. Koller, and K. Kärre, manuscript submitted for publication) from mice deficient in β2m/MHC class I, are recognized and killed by NK cells from β2m expressing mice. Interestingly, β2m deficient NK cells failed to kill the β2m deficient bone marrow and Con A blasts, further supporting the role of the class I environment in calibrating the NK repertoire (Högland, P., C. Öhlén, E. Carbone, L. Franksson, H.-G. Ljunggren, A. Latour, B. Koller, and K. Kärre, manuscript submitted for publication, C. Öhlén, manuscript in preparation).

“Protective epitopes” have been mapped to the α-1 and α-2 domains in a study of HLA transfected human NK targets (37), but the mechanism behind the effect is not known. It could occur either through a MHC class I mediated/presented negative signal to effector cells - the “effector inhibition” model (35) - or by interference with another NK target antigen - the “target interference” model (35). If the target antigen interfered with in the latter case was polymorphic and MHC
linked, this model can be reconciled with the recessive Hh antigen model (7). A recessive target antigen has recently been proposed for recognition of PHA blasts by alloreactive CD3⁻, CD16⁺ human NK cells. Resistance to lysis was dominantly inherited and segregated with HLA haplotype in a family study of lymphocyte target donors (38). If resistance is controlled by an HLA class I (like) gene in this human system, it may represent an analogue to the H-2Dd mediated protection from NK-mediated rejection of bone marrow (32) and lymphoma grafts (this study) in allogeneic or transgenic recipients expressing H-2Dd.

The rejection of H-2b lymphomas in the D8 strain was most pronounced in the lungs but was also observed in the liver. The small difference in splenic clearance was surprising, since the spleen is the standard source of NK cells for in vitro assays. For some previously studied tumors, the spleen was the primary organ for in vivo clearance by NK cells (13), while other tumors were cleared more efficiently in the lungs as in this study (14). The reasons for these differences are not known but they may reside in the choice of strains or tumor cells under study. Some tumor cells may express adhesion molecules specific for capillaries of the lung or liver, while others home primarily to the spleen. It is also possible that tumor cells arrested in the lungs can recruit NK cells from the circulation and the spleen, leaving fewer cells for tumor elimination in this organ. It should also be noted that highly active NK cells can be isolated from the liver as well as from the lungs (39).

The elimination of RMA-S in B6 resembled that of RBL5 in D8 mice both with respect to organ distribution and kinetics (Fig. 7). The main difference was in the strength of killing, which was one order of magnitude higher for elimination of RMA-S in B6 than for RBL5 in D8 (in both cases using RBL5 to B6 as control). This fits well with the rejection potential of subcutaneous lymphoma grafts in the corresponding host/tumor combinations (up to 10⁶ RBL5 cells rejected by D8 mice, but up to 10⁵ RMA-S cells rejected in B6) (19, 20, 28). The degree of H-2 mismatch between host and target in the two combinations may contribute to this differential strength. For RMA to D8 the only mismatch is the transgene, H-2Dd, while RMA-S lacks both K⁺ and D⁺ in comparison with D8 and B6. The NK mediated rejection potential against totally MHC class I/β²m deficient bone marrow grafts is also remarkably strong (36).

We conclude that an H-2Dd transgene can alter the NK repertoire in a specific manner in B6 mice, as most clearly demonstrated by the experiments with the RBL5 lymphoma and its mutant and transfected sublines. How then can the H-2Dd gene instruct NK cells in mice of B6 background to kill targets they would spare in non transgenic mice? One step towards the answer will be to determine the cell type in which the H-2Dd gene must be expressed. An interesting possibility is that MHC genes determine the repertoire of NK cells in situ, i.e., transgene expression in the NK₁.¹⁺ cell itself is necessary and sufficient. This and other alternatives can be tested through expression of transgenes controlled by tissue or cell type specific controlling regions. The neutralizing effect seen after introduction of the H-2Dd gene also to the target can be further explored with other transfectants expressing totally allogeneic, mutant or chimeric H-2 genes. Thus, our combined transgenic/transfectant system, may contribute to a molecular understanding of interactions between NK cells and targets in vivo.

We thank Dr. Gilbert Jay and coworkers, who provided the D8 strain.

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References
6. Cudkowicz, G., and M. Bennett. 1971. Peculiar immunobi-
ology of bone marrow allografts. II. Rejection of parental grafts by resistant F1 hybrid mice. J. Exp. Med. 134:1513.